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ABSTRACT

This project was a field research experience designed to enhance the capacity of middle and high school teachers to incorporate active research into their classroom teaching. Evaluation was designed for both formative and summative purposes. All activities in the project had the goal of using inquiry-based learning in the classroom. Teams of one teacher and two students (for a total of 44 teachers and 86 students) participated in pre- and post-institute field and research projects. The project staff worked with each team before, during, and after the institutes to assist with all project activities. The institute activities were used to give teachers sufficient practice doing fieldwork and active research. Teachers saw how the science techniques worked or did not work and learned to be flexible. Not only could students create their own questions and design experiments, but they could also use statistical procedures to test their null hypotheses. (KHR)

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Monarch Monitoring:
A Teacher/Student/Scientist Research Project

Final Report

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Executive Summary

Project Description

The Monarch Monitoring Project was a field research experience designed to enhance the capacity of middle and high school teachers to incorporate active research into classroom teaching. Active research was defined as students involved in formulating questions and/or designing research protocol, collecting and interpreting data, and reporting results.

All activities of the project had the ultimate goal of increasing inquiry-based learning in classrooms. Teams of one teacher and two students (total of 44 teachers and 86 students) from Minnesota and Texas participated in two weeklong resident institutes and participated in pre- and post-institute field and research projects back in their communities. Project staff worked with each team before, during, and after the institutes to assist with all project activities.

Project Findings

This National Science Foundation project did what it said it would do and did it well. By the end of the project, over 70% of the teachers were doing active research with their regular classes – only about 19% had attempted doing active research before this project.

The design of the project worked for these teachers. This was one of the best professional development experiences many had ever had. Project scientists were commended for their teaching skill – modeling the hands-on inquiry they wanted teachers to do back in their own classrooms. Participants judged the instructors were more effective because they had really done research.

Institutes activities gave teachers sufficient practice doing fieldwork and active research so that the research process became second nature. Teachers saw how the science techniques worked, or did not work, and learned to be flexible. With students there, they saw that students could do more than they thought, and they raised expectations for all their students. Not only could students create their own questions and design experiments, but they could also use statistical procedures to test their null hypotheses.

The three project pieces each contributed to the success of the project:

1. Monarch Monitoring was scientist-directed periodic monitoring by each team at a selected local site. While monitoring, teachers practiced field techniques and contributed data to a "real" research database. These data have been presented on the University of Minnesota Monarch Lab website at http://www.monarchlab.umn.edu/MP/results.html. Five to eight teachers continued monitoring with students even after the project ended.

2. The Team-Generated Research Projects were teacher/student/scientist team designed and conducted research projects on monarch biology through all stages of the research process including publication. Teachers practiced research techniques and gained an understanding for how tough it was to design and conduct "real" research. Projects have been published on

the U of M monarch website at http://www.monarchlab.umn.edu/Research/topics.html. These research projects made important and real contributions to understanding monarch biology. Teachers and students were excited and highly motivated to help create scientific knowledge.

3. For Translation to the Classroom, teachers developed goals and plans for implementing active research and other inquiry practices in their classrooms. Project staff mentors visited teachers' classrooms and provided technical support through e-mail. Teachers acquired knowledge of the biology and ecology related to monarchs. Even more important, they learned research techniques and practical ways to fully implement student-led research.

   Some teachers needed considerable support in order to finish their own research project and to help their classes set up experiments. The project staff provided a support system that most teachers needed, whether it was for materials (eggs and milkweed), email answers to questions, and/or site visits. With real research, real problems came up and teachers needed help. Sometimes the scientist being in the teacher's classroom was critical to the teacher learning to have students design testable questions.

   For many teachers, it was two years after attending the institutes before they were able to fully implement active research in their classrooms. Those who took less time had previously been involved with Monarchs in the classroom or had attempted to do real research to meet graduation standards. Most teachers were doing more each successive year to change activities and units to be more inquiry-based. Though monarchs proved to be special, easy to use organisms, many teachers also transferred active research and field techniques to other areas of their science curriculum.

   Teachers successfully adjusted their curriculum to incorporate fieldwork and active research even though these activities took more time. Teachers found they could use monarchs to teach many science concepts and skills. Teachers could meet science standards and graduation standards and help colleagues do the same.

Monarchs enriched the lives of teachers, students and their schools and communities; it was easy to engage others with monarchs. Successful science fair participation increased. Teachers received recognition and awards for their work on this project. Teachers were inspired to raise money to carry on their work with monarchs.

Summary of the project design elements that worked:

Effective modeling and extensive practice of what teachers were to do in their classrooms
A follow up support system, e.g. materials, scientist visits, and email communication
Continued assistance to teachers who needed time to try things out
Teachers coming in teams with other teachers and students
Classroom teachers included on the project staff
Time for teachers to meet and talk during the institutes and networking after the institutes
Monarchs – special organisms, easy for teachers to access and use with students

I. Introduction and Background

A. Goal of the project:

The Monarch Monitoring Project was a field research experience designed to enhance tne capacity of middle and high school teachers to incorporate active research into classroom teaching.

B. Evaluation Goals:

The evaluation of this project was designed for both formative and summative purposes. The purpose of the evaluation is:

1. To assess achievement of the teacher-related project outcomes
   (a) To increase the use of active research in middle and high school science classes,
   (b) To increase the use of field experiences in middle and high school science classes.
2. .To identify successful strategies for accomplishing these outcomes.

C. Activities of the Project:

All activities of the project had the ultimate goal of increasing inquiry-based learning in classrooms. Teachers in the project participate in two weeklong resident institutes and participated in pre- and post-institute activities back in their communities. Project staff worked with each team before, during, and after the institutes to assist with all project activities. These activities focused on two research projects and transference of formal research practices to teachers' classrooms.

Specifically, the three project pieces were:

1. Monarch Monitoring – scientist-directed periodic monitoring by each team of a selected local site;

2. Team-Generated Research Projects – teacher/student/scientist teams selected, designed, conducted, and analyzed an additional research project on monarch biology through all stages of the research process including publication; and

3. Translation to the Classroom – teachers developed specific goals and plans for implementing research and other practices in their classrooms, and project staff visited teachers' classrooms and provided technical support through e-mail.

D. Data Collection Strategies

Five groups of teachers and students participated in two resident, week-long research institutes. A total of 44 teachers and 86 students completed participation in both one-week institutes.

The sources of data that were used for this final, summative report include:

1. Teachers completed an initial written survey (prepared by CAREI research staff with input from project staff) designed to assess the level of use of (1) active research projects and (2) field experiences in their classrooms before they began the Monarch Monitoring Project. They have completed an identical follow-up written survey.

2. Groups 3, 4, and 5 completed a pretest of knowledge about monarchs before the start of the first institute and completed a posttest of knowledge about monarchs at the end of the second institute.

3. All groups completed written evaluations (prepared by project staff) at the end of both the first institute and the second institute in which they participated.

4. Twenty teachers were selected to participate in telephone interviews at intervals during the three years of the project. The criteria for selection were geographic location, grade level (middle or high school), and school district. Twelve were from Minnesota, two from Wisconsin, and six from Texas. Seven were from high schools, 9 from middle or junior high schools, and 8 from middle thru high school. Case studies were written and included in this report.
   Five Group 1 teachers were interviewed over three years after the institutes,
   Five Group 2 and four Group 3 were interviewed over two years, and
   Three Group 4 and three Group 5 teachers were interviewed over one year.

5. Teacher/student teams submitted their monarch monitoring data to project staff.

6. Team-generated research projects are displayed on the University of Minnesota Monarch website.

7. Evaluators observed institute activities at Wilder Forest.

8. Project staff wrote summaries of conversations with teachers during the institutes, summaries of their classroom visits.

9. Evaluators interviewed project staff after all institutes were completed.

10. Evaluators observed a reunion of available teachers at the Science Museum of Minnesota several months after the institutes were completed.

E. Recruitment of teachers and application process

In Minnesota, recruitment efforts included brochures distributed at Minnesota State Science Teachers (MnSTA) meetings, a direct mailing to MnSTA biology/life science members, announcements in Minnesota Science Teacher Association newsletters, Monarchs in the Classroom newsletter, Monarchs in the Classroom teacher courses, and other programs.

In Texas, the Monarch Project was announced in the Science Teachers Association of Texas (STAT) newsletter and on their web page at Http://statweb.org/monarch.html under professional development opportunities. The flyer was e-mailed to two major Texas teacher listservs through Vanessa Westbrook, State Science Specialist for the Texas Statewide Systemic Initiative. Flyers were also sent electronically to the Journey North Texas e-mail list. For Group 1, flyers were mailed to all members of the Texas Biology Teachers Association (TABT) with help from contacts at the Ft. Worth Museum of Science and History, as well as to all members of the Texas Association of Environmental Educators (TAEE) with the flyer inserted in their quarterly newsletter.

Part of the recruitment effort included sending multiple applications to teachers who requested information. For example, if the teacher did not apply for an upcoming group, they were sent applications for later groups.

In order to select teachers with leadership qualities, the teacher application asked for the following info:

1. We are looking for ***8th*** to 10th grade teachers who wish to grow professionally and are willing to experience and use project-based, research approaches in the classroom. We want leaders - teachers who are willing to learn and share their experiences with other teachers and students. You will be expected to provide at least one in-service workshop for other teachers.

2. Each teacher needs to submit two student applications, preferably one girl and one boy. These should be high-potential 9th or 10th grade student leaders willing to learn and share their experiences with others. Students will be asked to present the results of their research. Students of color are especially encouraged to apply.

3. Teacher/student teams must attend both institutes in their entirety - either April 6-12 and *August 15-21* or *June 13-19* and October 9-15, 1999.

4. *All participants, both teachers and students, must commit to conducting "at-home" research between the two institutes. This research will involve weekly monitoring of monarch populations, and a team-generated research project. It will require approximately eight hours a week for ten weeks, although team members will be able to cover for each other during vacations or other commitments.*

5. *All teachers must commit to facilitating ecological research in their classes, using techniques learned during the institutes.*

6. Four graduate credits are available for teachers through the University of Minnesota at a reduced tuition rate.

7. NSF requires that participating districts demonstrate a financial commitment to this project. Districts will be asked to contribute:

   a. Teacher travel (approx. $300)*
   b. 50% of teacher lodging (approx. $280)*
   c. 50% of substitute costs during the October institute in Texas
   d. Support for at least one class field trip to a teacher-selected field site
   e. On-line capabilities
   f. Support for project dissemination by teachers and students.

(Teachers answered the following questions)

1. In your opinion, what makes science instruction successful? What would help you improve your science teaching?

2. What do you do in your classroom to provide inquiry-based experiences for students?

3. Give examples of your own leadership activities that demonstrate your commitment to helping other teachers improve science instruction.

4. Why do you want to be part of this project? What value do you feel this project will have for you and your students?

5. (Optional) Is there anything else you want us to know that might help us in evaluating your application?

6. I understand that I am committing to working with the two students with whom I am applying on monarch ecology research projects, and that this research will require approximately one day per week over a ten-week period during the summer. I also understand that I am expected to share what I learn during this project with other teachers in my district, and with all of my students.

Signed: _____ Date: _____

F. Characteristics of participating teachers, schools, and districts

Participants in the five groups were composed of 44 teachers and 86 students.

Characteristics of the schools from which they came:

34 School Districts
- 7 = urban
- 12 = suburban
- 14 = rural
- 1 = suburban/rural

36 schools
- 14 = high schools (1 – home school)
- 5 = junior high schools
- 11 = middle schools
- 1 = k-12 school
- 2 = k-8
- 1 = 7-12 school
- 2 = 6-12

Student enrollment
- 11 = 0 – 500
- 14 = 500 – 1000
- 7 = 1000 – 1500
- 1 = 1500 – 2000
- 3 = Over 2000

Percent of students who qualify for free and reduced lunch for 24 schools
- 3 = Over 80%
- 1 = 60 = 80%
- 6 = 40 – 60%
- 11 = 21 – 30%
- 13 = 0 – 20% (included NA – private)

Student Ethnic/racial background of the 34 school districts:
- 11 = 95 – 100% white
- 8 = 84 – 91% white
- 4 = 62 – 80% white (one is 14% black and 14% Hispanic; one is 17% Hispanic; one is 26% Native American; two are 30% Hispanic, 5% black or other)
- 3 = 43 – 61% white (one is 13%Asian, 23% black; one is 28.6% black, 14.6% Hispanic; one is 20% Asian, 10% black, 10% Hispanic)
- 4 = 31 – 42% white (one 25% Asian, 21% black, 22% Hispanic; one 56% Hispanic; one is 12% Asian, 24% Hispanic, 26% black; one is 60% Hispanic, 5% Asian)
- 4 = 1 – 20% white (one 99% Native American; one 67.6% Hispanic, 11.3% black; one is 1% non-white; one is 60% black, 20% Asian;)

Characteristics of the participants:

44 Teachers
- 32 white
- 2 non-white
- 25 female
- 9 male

Highest Degree
- 21 Bachelors Degrees
- 22 Masters Degrees
- 1 Ph. D.

Years Experience
- 2 = 0 – 3 yrs
- 8 = 3 – 6 yrs
- 8 = 7 – 10 yrs
- 7 = 11 – 15 yrs
- 4 = 16 – 20 yrs
- 11 = Over 20 yrs

86 Students
- 52 female
- 34 males

- 73 white
- 4 Hispanic

- 3 African American
- 2 Native American

- 2 Asian
- 1 Ethiopian

G. School District Resources Committed to the participants, including on-line access for communications.

In addition to the required reimbursement to the Monarch Project for teacher airfare and 50% of lodging at both institutes, totaling $23,447 (Appendix A1), schools were asked to complete an in-kind documentation form (Appendix A2). These forms detail the in-kind amounts that districts contributed in the continuing support of field research, student projects, and technology/dissemination efforts resulting from their teacher/student team involvement in the Monarch Monitoring Project. Principals' signatures attest that the in-kind costs to support this continued implementation of research-based learning are not from federal funding sources.

The budget for this project anticipated each school district to contribute an in-kind amount of $500 for field research support and $500 for technology/dissemination support as the teacher implemented their new research-based curriculum. These amounts were expected to total $22,000 for the first 18 months of the project and an additional $30,000 for the second 18 months. (These non-federal dollars for teacher classroom support do not include the amounts in Appendix A1 for teacher travel and lodging reimbursements.)

Analysis of the in-kind documentation from districts (Appendix A3) shows astounding levels of commitment on the part of schools to support teachers' efforts in the classroom and in professional dissemination. With forms returned by 31 of 38 schools involved in the project, authentic cost-share from schools totals $102,578 or twice the anticipated in-kind of $52,000. Each of the 37 participating teachers in the 31 schools who returned forms has received an average of $1430 in field research and student project support in the forms of equipment, supplies, transportation, and planning time. Each teacher also received an average of $1360 for technology and dissemination in the forms of computer support, on-line access for communication, and software. The $3309 average, in-kind support per school far exceeds the $1000 cost share amount ($500 field research support and $500 technology support) budgeted as in-kind.

II. Institutes and Project Design

Description of the Institutes

Two separate, week-long, on-site institutes were held for each of five groups, one week in Texas and one week in Minnesota. With separate time periods and different locations, participants were exposed to two very different stages of the monarch life cycle. During the interim between the two separate institutes, teacher/student teams monitored home field sites for monarch abundance and carried out an independent team-generated research project.

All participants and staff were housed on-site during these weeks in order to forge long-term relationships between students, teachers, and scientists. The content of the first institute included information about monarch, insect, and plant biology; techniques for monitoring home field sites; experiences in conducting a research projects; and planning the team-generated research projects (including choosing a research question, formulating hypotheses, and developing data collection techniques).

During the second institute, similar activities were conducted in order to compare monarch ecology in Minnesota and Texas. Participants also presented and began analyzing the data they had collected since the first institute for their team-generated research project. After Group 1, sessions were held during both institutes for teachers to address issues of translating what they were learning to their classroom teaching.

Whenever possible, a scientist mentor visited each team at least once during the summer to help with team monitoring and team research projects and/or during the fall of that school year to work with the teachers in their classrooms. During the classroom visits, which lasted up to one entire school day and often involved an overnight stay with the teachers, mentors worked with teachers and students on some classroom lesson that was related to inquiry, field work, or monarchs. In some cases, mentors gave research presentations in the teacher's classes. The goals during these visits were to help the teacher facilitate inquiry-based learning in the classroom, to give the teacher a time to visit one on one with a scientist staff member, and to observe how implementation was progressing.

Changes Made in the Institutes during the Project

Teachers and students completed feedback questionnaires after each of the two institutes, and project staff gathered feedback during site visits. Participants raised several concerns and made several suggestions for improving the institutes. Project staff made a number of adjustments for later groups.

More free time for students

Teachers in Group 1 recommended that more free time and recreation activities be provided for the students. Group 1 participants all worked on project activities from about 8:30 a.m. to 9:00 p.m. every day during the institutes, with few breaks.

Project staff reported about later groups: *"While we still work with teachers for this amount of time, we have scheduled other student activities during evenings and other times during the day. This gives the teachers time to socialize and process away from the students, and vice versa."*

Role of teachers as students

A few members of Groups 1 and 2 expressed some discomfort with not knowing when they were students and when they were teachers. With later groups, project staff deliberately discussed with teachers that they would be changing roles from student to teacher to student during the two weeks. Some members of Group 3 volunteered that they "loved the teacher role change."

Starting with Group 2 the staff sent a letter to teachers that explicitly stated expected teacher roles.

> *"During this course, you will be both a student and a teacher. As such, you will take on several roles and will have to manage changing hats. As the workshop begins, you and your students will work together as active, involved learners. It is exciting for students to see their teachers as learners, and this project will give your students a chance to interact with you as peers. We will ask you to behave as model students—projecting enthusiasm and curiosity, and generating and answering questions. As the course progresses, you will need to resume your role as teacher, or more specifically, as a facilitator of inquiry-based learning. You'll need to step back and let the students generate and answer most questions, while you play a guiding role in the research projects, helping them to plan and carry out projects based on their ideas. Finally, you will also be a chaperone, and will be asked to make sure that the two students you bring behave appropriately during the workshops. We hope that these multiple roles will not be too difficult to manage. Our evening teacher meetings will give you an opportunity to work this out with others in the same boat!"*

Time for teachers to meet and talk as teachers

Meetings of project staff and teachers were not part of the Group 1 institutes. Group 1 teachers suggested that more formal time be scheduled for teachers to talk about teacher issues. Project staff scheduled formal teacher sharing time starting with Group 2. Project staff reported, *"We really worked out how we were going to do the teacher meetings. We developed a structure for the meetings and what we wanted to accomplish and what we needed to process with them."*

Teachers' perceptions of how well the staff/teacher meetings taught them improved with successive workshops with Groups 2, 3, and 4 (mean of 3.55 for Group 2, 4.20 for Group 3, and 4.56 for Group 4 on a scale from a low of 1 to a high of 5). Perceptions of how the staff/teacher meetings would affect their teaching also improved (2.75 for Group 2, 4.30 for Group 3, and 4.44 for Group 4). Group 5 was much less positive about the benefit of these meetings for what they taught them (mean of 3.43) and how the activity would affect their teaching (3.29) (see Table B1, Appendix B).

Most comments about the teacher/staff meetings were positive. The teacher/staff meetings were for processing, debriefing, and sharing concerns. Teachers said that the staff "*kept us focused and gave us a format to talk about concerns.*" Two teachers would have liked still more help using what they learned *"with traditional classes"* and "*managing several inquiry projects at once*" in a regular classroom.

There were a few teachers scattered across groups who had a hard time with the staff/teacher meetings being at the end of the day, which was in the evening. One said, *"I'm too tired to think by that time of day."* Suggestions included meeting early in the a.m. or having a working lunch in a room next to the dining room, but the schedule seemed to work for the majority of teachers.

Amount of work expected of teachers and students
There were a few teachers across groups who suggested the schedule was too strenuous and they *"felt fatigued."* They suggested scheduling more *"down time."* Requests ranged from *"be allowed 5 minute breaks to go to the bathroom"* to *" more 'free' time to read/go over info received & taken as notes in order to digest & assimilate."* One teacher suggested, "We *could have more time to complete each activity and we could work at a more relaxed pace."*

Some teachers suggested that there be more information sent to them ahead of time about the schedule during the institutes so that people would know it was *"a lot of work."* A couple teachers wanted *"a clearer picture of what's going to happen [so that we can make] choices of students who are "better" capable of working under the intense environment of group research."*

However, most teachers liked the busy schedule and thought the pacing was *"excellent."* Even those who might have liked more free time did not want any content or activities excluded from the institutes. Project staff members were mindful of the feelings of the teachers but felt it was important to utilize all the time they possibly could.

A classroom teacher on the project staff
After the first group, the project had a teacher from a previous group become part of the institute staff. Project staff thought these teachers were so effective because they could say, *"This is how I do it, and all my students do independent research projects. This is how they come up with questions, and this is how I manage mentoring with all these different projects."* One teacher who taught seventh grade was particularly helpful because she could say it worked with younger students. Project staff said she was an incredible role model.

Project Staff General Feedback on the Institutes

Planning and processing time
It was evident that the project staff did considerable planning in advance of holding the institutes and during each of the institutes. Project staff reported spending a great deal of time processing during the institutes. The staff was all from the same department at the University of Minnesota, and said they *"talked about it so much." "We had meetings that lasted six hours when we were planning these things, and we just really processed and processed and processed."* During the institutes, University of Minnesota staff (all women) could debrief in their shared dormitory-like room and make plans for the next day.

Learning from things not working – staff and teachers
Institute activities evolved. Project staff said they made many mistakes with the first group and had *"really changed a lot."* But experimenting with the first group was not without benefit to teachers. Said one, *"I think the first group got something that the rest of the groups didn't get. They saw us*

have to be able to deal with a lot of things that didn't work out. There were projects that we did the first year that we said, 'oh! well, that completely didn't work, but here's what we can learn from that' and 'oh, there aren't any ants out today, so let's study something else.'"

Group 1 teachers agreed that they learned from the project's early trials. Teachers said, "*I liked that not everything worked because that's how people learn to solve problems.*" Staff thought teachers "*learned that you can go into a situation with your class, not knowing anything about it and make it work, and they learned a lot about being flexible.*" Staff said it was somewhat different for the next groups because they "*had Plan B's for a lot of things*" although they still had to scramble some. "*Some teachers learned from that, and some teachers thought that was a failure on our part – to have bad weather or whatever.*"

Teachers coming in teams

Staff members were convinced that having the teachers come in teams was really helpful. They gave examples of teams that seemed to do better with the project than teachers who did not come in teams. They felt it was because there was someone else depending on them at their school, they motivated each other, and they had someone to go to when they were stuck. One said, "*When it's not working you have someone to talk about it with that maybe isn't as hard to reach or as intimidating or as removed from the classroom as we are.*"

Classroom visits

Project staff thought having field visits and classroom visits was very important, but that some classroom visits could have been more productive. They felt more structure was needed to help teachers know how to use the scientist's support. Project staff developed a sign up sheet for later groups that had possible things that the scientists could do. That helped many teachers, but there were exceptions.

Staff were not sure what would help the exceptions. They thought about being more directive, saying, "*We're going to do this. We want to talk to your kids about doing an experiment, even if they haven't even started to do it yet, put out some objects on the table, and we'll help them make observations and come up with questions.*"

Their favorite classroom visits were those where they helped students come up with questions and/or helped them think about their methods and analysis. One scientist said, "*When kids were actually doing experiments and we came to help with that, I think that was a big help for the teachers.*"

Teacher Feedback about the Institutes

General comments from teachers about the institutes

All teachers said they met most or all of the goals they set at the beginning of the institutes. Many said they exceeded their goals "*by miles.*" Examples of the many positive general comments were: "*What a growing process!*" and "*The entire experience was an incredible learning journey!?*" "*I know it's incredibly expensive, but it's incredibly valuable.*"

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Didn't want to be done

When asked what they wished about the institutes, many said, *"I wish we could continue"* or *"I wish we could come back next year,"* or *"I wish we could have a reunion in Mexico to see the final piece of the migration story."*

Best ever

Many volunteered that this experience was the best or one of the best they had ever experienced.

> *"I have done a lot of workshops. I have been a Danish exchange teacher, done science in the Rockies, and this ranks up there at least with the top couple."*
>
> *"It has been an outstanding experience. It's been the most successful National Science Foundation Project that I've worked with, and I've done quite a few."*
>
> *"This is my eighteenth year of teaching high school biology and environmental science, and I can truthfully say that the educational experiences gained by both me and my students through our monarch migration and larval monitoring research far exceed any previous learning experiences we have ever had.*
>
> *"One of the best things that had ever happened to my teaching. . . . So many workshops I go to are pretty worthless. I sit there and I might glean one or two good things from them, but I'm sitting there for hours and hours, going, 'uh, I paid for this?' But this one was non-stop learning, and I felt like I'll never be able to put all of this in the classroom because there's just so much."*

What teachers learned

Teachers gained specific knowledge about monarchs and related ecology and learned research techniques. They learned and practiced doing scientific research and felt prepared to take some or all of what they learned back to their students. See Section V. Transfer to the Classroom for much more on this topic. Feedback from participants was quite positive.

Learned to teach the scientific method

Teachers learned how to have their students do scientific research; they felt it made them better teachers. For example:

> *"For the first time, my students are conducting valid, meaningful, scientific research and are learning first hand about the trials, tribulations, and jubilation of doing research. . . . It is the most valuable learning and teaching tool I have ever had because it incorporates inquiry, scientific processes, data analysis, ecology and stewardship all wrapped into one package."*
>
> *"This experience gets you excited to teach science and gets you prepared to use the scientific method as an inquiry tool for everything because you can see it works for any experiment you ever want to do. You can have the kids set it up instead of giving the kids the worksheet. It makes you a better science teacher."*

Test of science knowledge

Groups 3, 4, and 5 completed a pretest and posttest of science knowledge about (a) monarchs and related plants and insects and (b) research and analysis skills. The pretest was completed before the start of the first institute and the posttest at the end of the second institute. The test, expected answers, and scoring rubric for rating the responses are found in Appendices C1, C2, and C3.

The differences between pretest and posttest scores were statistically significant ($P < .001$) when doing a matched-pairs t-test of 23 teachers responses (see Table C1, Appendix C1). This result came about notwithstanding a number of participants had been involved with Monarchs in the Classroom before this project, and therefore, started with high scores. Differences among the participants decreased considerably by the end of the two weeks of institutes.

Didn't expect to learn

Teachers were asked what they learned that they did not expect to learn. More than half of the teachers wrote that they did not expect to learn about the statistical procedures they were taught during the second institute. Many listed particular items of scientific knowledge they did not expect to learn. Other items that some teachers learned that they did not expect to learn were: how to effectively brainstorm, making effective presentations, writing a scientific paper, how to do a research project with students, and how to change "cookbook" labs to inquiry labs.

A teacher wrote that she did not expect to learn "*that this format of a community of learners is a great way to learn.*"

Organization of the institutes

Teachers were very positive about project staff and the components of the project, including the format of the institutes.

About project staff

Teachers were quite positive about the project staff, Karen Oberhauser and the graduate students.

> *"I think Karen and her grad students put in a lot of time working on these things and getting things ready for us to use. They did an excellent job."*
>
> *"I was just absolutely amazed at how good a job Karen and the grad students did working with the kids and with the teachers." "Seeing them interact with the kids that we brought, who weren't always angels, and then the teachers who were also a pain in the neck to work with, they were just really patient and knew how to explain things, and they modeled everything."*
>
> The year after participating in this project, one teacher attended a workshop at the Botanical Research Institute of Texas (BRIT). She said it was one of the best inquiry teaching workshops she'd "*attended locally **ever**.*" The woman responsible for the workshop had been a student of Dr. Oberhauser. The teacher said, "*They are sitting on a gold mine at the University of Minnesota.*"

Interacting and learning from research scientists

Many teachers were pleased to get to know and work with "real scientists" and to know that there were scientists who cared about improving science teaching and who were so excellent in modeling effective science teaching techniques. Teachers would not want to "*give up having the researchers. It's SO important to have people who have really DONE research.*" Most teachers had never done "real" research.

> "*But what Karen and her staff did for us is talk about how do we apply the scientific method to how scientists really do their work? . . . And it helped me to be able to explain to my students more clearly how they can apply the scientific method.*"

It was how teachers learn

Several teachers said this project matched how teachers learn. One said, "*Instead of being 'told' how to use inquiry learning, we were taught by inquiry learning. By experiencing the process several different times, the techniques became second nature to me. Not surprisingly, I learn in the same way my students learn – by doing.*"

One teacher thought even a super-traditional teacher colleague of hers would learn through a program like this one. "*For me to tell him, he's not convinced. If he actually had to go muck about and run around and chase monarch butterflies in the woods and do stuff, it would work really well. That kind of training, where you bring kids and teachers together and make them work, I thought really worked well. That whole process, of a teacher bringing two students and seeing how well it worked with those students, was huge.*"

One teacher said it was particularly important to do the specific activity during the institute so that she could see how it worked. "*We can pull up something on a web site and read about it, but so what, you don't really know how it works until you've done it.*" "*You have to have a feeling of how it's going to work.*"

Teachers were very positive about the many mini-investigations they did and about the way groups were formed and mixed up to do the investigations. Many participants said that the number of times they were required to do all the steps of a real experiment was very important.

> "*We did so many mini-research research projects, like migratory habitat, monitoring the roosts and making census, sex differences in the behavior of the monarchs in the tents . . . We would divide up into four teams, you'd collect data, and come back, share your data, make transparencies, maybe do a statistical analysis, and then present your results to the big group. We had to do this six to eight times . . . you really got kind of good at it.*"

Institutes as a model for teaching

Many teachers volunteered that they felt that the activities of the institutes modeled for them how to do the various activities back with their students. They learned how to lead students but to let students think through their experiments.

> "*Right away Liz told us, 'Now if they need some help, then offer some suggestions.' Normally, I'd say, 'Okay, today we want to learn about caterpillar behavior. Here are some suggested*

areas.' And we didn't do that and those kids came up with some of the greatest things. And I think we stifle some of their creativity because we say, 'Here's what we want you to look at.' And just because we're adults, we don't necessarily know everything either. So I really learned to be a lot more of an exploring type of teacher."

University support including classroom visits

Project staff found the visits to teams valuable on both ends. Staff saw the program "in action" and made changes based on what they observed, and participants received timely feedback on their research methods.

Project staff thought some teachers really liked having a scientist come into their classrooms, and some teachers felt intimidated. A staff member said, *"For the teachers who were not doing much on their own, it just would have been nice for us to give them a little more support in the classroom to show them, that "look, you can take parts of this and do it. The teachers that got that on their own and had their kids doing those kinds of things really benefited from the classroom visits."*

Follow up was important to teachers

Teachers felt the follow up from project staff was an important part of the project. Everything teachers said about the follow up work of the project staff was positive. Many teachers kept in contact with University of Minnesota mentors through email and found project staff very responsive. Most teachers ordered eggs, larvae, milkweed, and/or BT toxin from the University.

"Karen and her staff provided me with a lot of support that I needed to have the confidence to be successful with this program. Sometimes we train and we train, and we send them home, and we never talk to them again. I'm guilty of that, too. That's not very good. That's poor practice."

"It helps to have a support system in place. If I had questions or if my students had questions...and there WILL be lots of questions that you can't answer. There WILL be times when you're too busy to really give something the thought that it needs to be given . . . sometimes you have unforeseen problems anyway, they're just more serious if you don't think through it clearly ahead of time. Having a support crew in place, the University of Minnesota was our support crew, [is important]."

Sometimes just being available was important to project teachers.

"To know that I could get live specimens . . . And I know that Karen Oberhauser has a website that we could access. This has sort of expanded our horizons quite a bit, to know that I could get some of these things and get going and get the students involved in raising the monarchs, tagging them, following them even on the website."

How project staff helped in doing monitoring and the research project

A University of Minnesota mentor worked with each research team and tried to visit the team to help with the project. Teachers and/or students often needed answers quickly; they found

University of Minnesota mentors essential to successful completion of their research project. Two examples are:

> *"I've been in constant communication with Karen and Michelle up in Minnesota. . . . I was e-mailing them probably daily for a while there, until we figured out the design of the experiment. We had an original plan, but then it seemed like nothing was going right, and so we were in communication all the time."* She felt that without access to e-mail their project *"would have fallen apart."* For example, *"if you've got these butterflies that are laying eggs and now the plants are dying, what do you do? You can't wait to try and call someone and hope they return your call. You didn't have to worry about telephone tag."*

> *"When my monarchs were going into the chrysalis, and they were going into the J and dying . . . I was able to e-mail them and find out. Some of the monarchs had been parasitized by the fly that lays the eggs into the monarchs, and I didn't know that. And then they would e-mail me back, and they would say, look for the pupae in the bottom of the container and sure enough, it was there. And I just didn't know to look for that."*

Sometimes the help was with specific parts of a project, such as an oral presentation or display boards.

> *" The two students that were with me made an hour presentation to about 15 people. Dr. Oberhauser came out and worked with us in the afternoon, and so they were able to do the presentation and then stand for questions. . . . [Michelle] worked with us in gathering data this summer a couple of times, and after [the presentation] they helped us start crunching numbers and gave us some ideas again . . . So they are very helpful."*

> *"Liz was the specific researcher that helped us with our project. We worked with the girls on setting up the display board – some things to think about. She was very, very helpful."*

<u>Project staff helped teachers in the classroom</u>

The University of Minnesota mentors went into classrooms and modeled inquiry methods with the teachers and their classes.

> *"[Our mentor] came and talked to each one of my classes about variables, about what you need to think about, about making a testable hypothesis – she was wonderful."*

> *"Having [the mentor] come to my classroom to work with my students using inquiry methods was excellent. My students struggled at first but then fell in step with her guidance, quickly changing from "just tell me the answer" mode to a thinking mode that led them to ask 'what if.' In addition, they were able to begin to think through the issues of designing a good experiment."*

<u>How visits from scientists impacted students</u>

Teachers found the impact on students was greater when they could see a real, live scientist than when their teacher told them what scientists do.

Several teachers from urban schools mentioned impact on special needs students. For example, one teacher sent an email: *"Thanks for visiting our classrooms and for the help with our experiment after school. It's always nice to have someone from the outside world take the time to understand what our lives are like at Humboldt. It was really fun for me to watch you teach my students. You did a great job; they usually don't respond to 'strangers.' I told Racine (the girl by Michelle) that you were impressed with her, and she said, 'Thanks Ms. Layde, you made my whole weekend!' (Racine has an extremely abusive, dysfunctional, unnurturing homelife and gets all of her encouragement from school so it was nice for her to hear something positive from someone 'important'). My students were also baffled by the fact that you were a scientist but could also teach."*

Monarchs: A special organism

Project staff felt that the reason so many teachers continued to work with monarchs was because of the ease with getting the materials. With the monarchs, they can get the eggs, they have learned how to take care of them, and they know how to raise them. One teacher agreed that monarchs were easier than other field experiences because she could have milkweed and monarchs close by.

> *"The paperwork that we have to do to take them out into the field makes it hard to go on field studies. Getting the permission slips and the transportation and all those things. There are not any ponds or creeks or rivers right here on the campus, but with the milkweeds and the monarchs, they're right outside the window."*

Without being asked, many teachers explained what was special about working with monarchs in the classroom. First, students really liked working with monarchs, and teachers found that students cared about the monarchs.

> *"The students are very excited about having the monarchs in the classroom, working with the monarchs, handling the monarchs. I don't think I've met a student yet that doesn't like butterflies. The kids are excited to come into the classroom, to learn how to handle them, to be able to release them. They're real interested in the real life aspect of it."*

> *"The appreciation, the compassion for another living being, and just their whole approach to the ethics of handling it and the research and caring for the animals while they're here. Before hand, they're just bugs, and afterwards, 'that's my monarch!' And they're very concerned with, 'are they going to make it to Mexico okay?' And are you making sure you're giving them enough food?' 'Their cage is looking kind of bad. Can we clean it out?' They talk about it all year. They're asking ' have you heard anything about our monarchs?'"*

Teachers were excited about what the monarchs did for the quality of their teaching. Teachers found monarchs easy to adapt to inquiry-based learning and many aspects of science.

> *"Working with butterflies has really infused my classes with a lot of energy and excitement, more than anything else that I've ever done in teaching."*

"When working with other teachers, it's so easy to get them enthusiastic. [The monarch] has so much to offer, and there are so many different avenues, no matter what grade you're teaching. There are just so many ways you can use this organism to teach science and kids respond so well. So it's an easy sell." "It's hard to replicate that in other areas."

Teachers received recognition and awards

Some teachers talked about the respect they felt from students for what they gained during this project. *"The students look to me as an expert in the field or an expert in this area with monarchs, so you get a certain amount of respect from them just from having been involved in all of the research. And so that's been real beneficial."*

One Texas teacher was selected to be a Tandy Scholar – 100 outstanding teachers selected each year. She was also selected as one of three teachers from Texas to receive a Presidential Excellence Award in math and science teaching given by the National Science Foundation. They also received an EPA grant to work on this and other grants. All of these happenings resulted in newspaper coverage every 2 or 3 months the first year after she attended the institutes.

The Presidential Excellence Award meant her school received $7500. *"This money allowed me to take 12 students on the fall migration field study trip to the Texas Hill Country instead of just two, and I was able to help pay the way for our San Antonio partners to come meet us. The money will also allow us to fly Karen here to help us. It is providing equipment for the GLOBE program and much, much more over the next couple of years. Without financial help like this, I could not do the things I do."*

One of the project teachers was asked by his principal to submit an application for the President's Award. The teacher said, *"Had I not gone through this experience and adapted some of this stuff to my teaching, I don't think I would be the Minnesota selectee."*

One team was very excited about the international conference they were invited to attend. There were researchers from Australia, Mexico, Canada, and the United States – about 100 participants and about 15 students. The teacher told the two girls, *"You're being thrown into an adult world here, so hang on."* She said the conference was very intense with presentations, but the students did great.

Another teacher's work was noticed by his school district and his community. He said the district support had been above and beyond. He had received e-mails from the superintendent, curriculum director, and principal. The district newsletter did a big article on what his department was doing. The city recognized him one year as an "environmental champion," which was front page in the local paper.

One teacher was chosen to receive one of five highly competitive monetary school awards and received $4,000 for the monarch project.

Inspiration to do additional similar things

One teacher said this project encouraged him to look for similar things. An example he gave was a web site that he found from Kansas that was devoted to student-teacher-scientist collaborations, and he was looking for other summer institutes where he would actually be doing some research, not just taking a class.

One teacher tried other new activities in the years since the institutes, including using Wisconsin fast grow seeds, adopting a stream for the Texas Watch Program, and being trained in the GLOBE program. She felt she would not have done these projects were it not for the inspiration of the monarch institutes.

One teacher was looking forward to participating in another project during spring and summer 2001. *"I'm involved with the Science Museum of Minnesota, and we've got a Lucent Technologies grant. We're working with teachers from [two other high schools], and we're developing an Earth Science curriculum that teaches Earth Science content through scientific investigation."*

One teacher talked about the how the international conference helped her with ideas.
"When I was at that conference last week, I took I don't know how many pages of notes. I have 151 new science fair projects written down. And I have the scientists for them to contact to find out more about how they can do these experiments. And so these are things that keep my teaching vitalized. It keeps it young, I guess. Otherwise, if you just always do the same thing the same old way, you're going to get bored and tired."

III. Team-Generated Research Projects

Description of Team-Generated Research Projects

Teacher/student/scientist teams selected and designed research projects on monarch biology. These projects involved the teachers and students in all stages of the research process, including generating questions, hypotheses, and designing methods. Teacher/student teams were encouraged to collaborate with one or two other teacher/student teams on a joint research project. One scientist worked with each of the teams.

Each group began their team-generated research projects during their first week-long institute. The teacher and two students from a given school worked together. For most team projects, two or three teacher/student combinations collaborated. Most collaborative groups did a paper together, but sometimes the research diverged when conducted at different sites, and separate papers became more appropriate.

The teams worked on their team-generated research during the interim between the two institutes. At the second institute, teams continued working on their projects, trying to assess where they were and what still needed to be done. Both teachers and students learned how to use statistical formulas to prove whether the data they had collected and graphed really did show anything important.

Changes made by project staff during the project

Project staff changed requirements for Groups 2 through 5. With Group 1, staff had a difficult time, *"like pulling teeth,"* to get teams to finish their projects. Teachers had already received their stipends; they had already been assigned their grades. They had less incentive to finish that part of the project. For succeeding groups, the timing of the stipend payment was changed. Project staff understood that the research was a hard task for teams when they have never done anything like that. Teams started the project during the institutes, but they needed deadlines for finishing after they went back home.

With Groups 1, 2, and 3, some teams had different ideas of what the student's role should be in writing up the project. By Groups 4 and 5, project staff felt they did a somewhat better job clarifying that though they wanted them to work as a team, in the end it was the teacher's responsibility to get it done. This was a teacher enhancement program though a lot of the teachers saw it as an opportunity for these two students to do research.

Status of the Research Projects

Completed team-generated research projects have been posted on the University of Minnesota Monarch Lab web page located at http://www.monarchlab.umn.edu/Research/topics.html. By September 2001, there were 27 different papers completed. Twelve were done by teams of teachers and their students (one team did 3 papers), and 12 papers were done individually by a

teacher and his/her students. One paper was done by a student (Group 1). Project staff reported in September 2001, that two teachers were nearly completed with their papers; three teachers would not be completing a research project. In Group 3, one teacher did an alternative project.

By group: (after group numbers are the number of teachers in that group)

Group 1 (9):	3 teams (7 teachers)	1 student individually	2 teachers no project
Group 2 (9):	3 teams (6 teachers)	3 teachers individually	
Group 3 (9):	2 teams (5 teachers)	2 teachers individually	1 teacher no project
	1 teacher did an alternative paper		
Group 4 (10):	3 teams (6 teachers)	2 teachers individually	2 teachers still working
Group 5 (7):	1 team (2 teachers)	5 teachers individually	

Project Staff Feedback on Team-Generated Research Projects

Karen Oberhauser was surprised that this particular teacher enhancement project required more follow-up and hand holding than other work she had done. She found the teachers had little experience with research. They did not know how to write a scientific paper, and they needed more visits and phone calls than anticipated. Several teams found their research very hard for them to do without considerable help.

Another staff member was not surprised because this research work was something that was uncomfortable, new, different, threatening. Even if teachers had done some type of research for a master's project, it was not to the scientific level they were being taught here. His experience had taught him that whenever a new pedagogy or new topic was introduced to teachers, there was always "*a lot of hand holding involved.*" He felt it takes a while for teachers to feel comfortable.

Another staff member thought time was the major factor for teachers. They have many other things that are part of their teaching days besides this research report. It did not surprise her that it was not their highest priority, and that teachers needed to be contacted to keep them thinking about it.

Staff thought getting teams to do research was important and was, in the end, successful. They thought that if all of the research had been done in the setting of the institute, it would have been much more difficult for teachers to take it back into their classrooms. The time between the two weeks was crucial for getting the research done.

> "*We helped them design the project so that they could do it with the resources in the location and everything else that they had near their school. Not having us right there was important. They had to be independent, and they saw that it could succeed. So I think one of the best things about this project was having an interim between those two intense weeks. They did it, and we helped them while they were doing it. We had constant e-mail and almost all of them got a visit during that time. And then they came back, and most of them were done so we could analyze it with them.*"

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Teacher Feedback on the Team-Generated Research Projects

During the Institutes (See Table B1, Appendix B)
Groups 1, 3, and 4 teachers rated "working in teams to design research projects" quite high for how the activity taught them (means 5.00, 4.70, and 4.78 respectively on a 1 to 5 scale with 5 being the highest rating). Groups 2 and 5 rated the team project a bit lower though still positively (4.11 and 4.28 respectively).

All groups except Group 3 rated "how the activity would affect their teaching" quite high (means 5.00, 4.70, and 4.67, and 4.85 respectively on a 1 to 5 scale with 5 being the highest rating). Group 3 teachers rated the team project a bit lower though still positively for how it would affect their teaching (mean of 4.33).

Case study teachers after the institutes (For full case studies see Appendix D)
The twenty case study teachers were asked about which parts of the project were the most useful to them. A number of them mentioned the team-generated research projects.

Teachers could practice doing research
The project gave teachers a chance to practice and become more comfortable with the techniques and to learn more about research than they would have without the project.

> It "*makes you go home and do what you did.*" "*A lot of times you will go to a workshop . . . and then go home and you don't practice it, and it's not yours until you have.*"
>
> The team-generated research project "*was probably one of the biggest learning experiences I had. It helped me realize how tough it is to design an experiment, how hard it is to think about everything, and how important it is to have a couple trial runs and practice. I feel that I am much more equipped to teach students how to do research projects than I ever was before.*"

Use the project as an example in classes
Several teachers mentioned that they used the team research project materials with their classes.

> It was "*something concrete in my classroom that I can refer to.*" "*I can say that I worked on this with students, and I was a co-learner, and it's nice to have it.*"
>
> Another teacher said he and his classes could use and add to the U of M data bank for years to come.

Experiencing real research
One teacher thought the team-developed research project had shown the students that "*science is really alive and is something that you really do.*"

One team had to deal with a major disappointment – the discovery of spores on their eggs. The teacher put the best face on their experience. "*Students had the opportunity to experience problems during research that real-world scientists often encounter. They also had an opportunity to study*

spores more in depth, and collaborate with research scientists on how to best deal with their unwanted problem."

Demonstrate graduation standards to a school board

One teacher used the team-generated research project to show the school board about graduation standards. He said, *"This is the kind of work that grad standards are about."* Dr. Oberhauser had come out to help them prepare for a presentation to a group of parents and teachers and then to the school board.

Inspired to continue research

Several teachers were continuing to do their research in successive years beyond the project. One team had been asked to replicate their research a second time during fall 2001. They were doing an experiment on simulated acid rain. The findings were interesting to the scientists. The teacher said, "W*hat we found out was, the caterpillars that had the strongest acid rain came out the largest. . . . Karen and Bill – all of them – were just flabbergasted, because all the other kinds of testing that's been done says that acid rain retards growth, makes things weaker, smaller, deformed."* The students on the team thought molting protected the larvae from damage from the acid rain.

Two Texas teachers planned to continue collecting data for a migration study they worked on with teachers and students in Minnesota. This team-generated research project began during the summer of 1998; the teachers were the same though the students changed over the three years as they moved on in school. One Texas teacher said, *"We are currently negotiating with Karen Oberhauser to see if we can fly her here to work with us for a few days to evaluate our data and prepare a professional paper."*

IV. Monarch Monitoring

Description of the Monarch Monitoring Activity

Teacher/student teams were to collect weekly data at their home locales on monarch abundance in all stages of the life cycle, using consistent methods that allow comparisons of relative numbers within and between sites over broad temporal and geographical scales. The techniques that teachers and students used included: observing and recording larval and adult behavior in the field, assessing the abundance and quality of larval hostplants, recording the presence and abundance of other invertebrates, including potential predators, on larval hostplants and elsewhere in the larval habitat, assessing larval and adult densities using censusing and mark-release-recapture methods, and providing detailed descriptions of their monitoring site.

Project staff felt the data would provide important information on monarch ecology: use of different kinds of habitat, the stages at which most mortality occurs, and spatial and temporal patterns of abundance and reproductive development. The monitoring research was largely scientist-directed with the scientists generating the questions and methods.

One of the goals of the monitoring was to have teachers practice doing a relatively simple field investigation that can be done with large numbers of students.

Changes made by Project Staff during the Project

The institutes were held earlier in the summer of 1999 to alleviate the problem of time for teams to work on both the monarch monitoring and the team-generated research projects before coming to the second institute.

Status of the Monitoring Project

Data from the monitoring piece of the project have been presented on the University of Minnesota Monarch Lab website at http://www.monarchlab.umn.edu/MP/results.html. Most teacher/student teams did some monitoring even though not all monitored enough time to have their data on the web site. Project staff, who visited teachers to help with the monitoring, were aware of a few teachers who did monitor a sufficient amount but did not submit their data. Overall, 30 of the 44 teachers submitted monarch-monitoring data. Several Texas teachers had difficulty finding an appropriate monitoring site in their area.

By group, teachers returning data were:
Group 1: 6 of 9; Group 2: 7 of 9; Group 3: 6 of 9; Group 4: 7 of 10; Group 5: 4 of 7.

All of these data are included in the database at the University of Minnesota and can be used for analyses. Five teachers from Groups 1, 2, and 3 have definitely continued with the monitoring and sending in their data. All of these teachers included students in their continued monitoring

activities. Three Groups 4 and 5 teachers have expressed interest in continuing their monitoring, but project staff will not know for sure until they send in data.

Project Staff Feedback on Monarch Monitoring

Project staff reported that the component of the project teachers and students followed through on the least well was the weekly monitoring. If project staff were to include this requirement in future teacher development, they would structure it differently.

Like other parts of the project, there was variance in what teachers took away from it. Some teachers did very well with the monitoring piece under difficult extenuating circumstances. For example, one teacher in Texas monitored every week during the summer in 100 degrees temperatures. She was still doing it for the third year, and she had students involved each year. The project staff person who supervised monitoring activities felt that this teacher had a natural curiosity about finding out what monarch populations were like at their site – a natural scientific curiosity. That was what she found with other people she worked with on the monitoring. She thought this teacher liked the reward of having the data be part of a real monitoring project.

Project staff estimated that about 50% of the teachers who started did a very good job the first year after their training, and about 20% will continue to monitor in years beyond the end of the project. They felt the ones that were continuing to monitor really gained a lot, and they were doing a great job. But they also felt that even though many were not continuing with the monitoring, most were continuing with at least the classroom part of what they have learned.

Project staff said they did not realize how difficult it would be for teachers to do something in the summer. As ecologists, the staff scientists were accustomed to doing their work in the summer. It was an eye opener, seeing how hard it was for teachers to work around their vacation and their students' vacations and commit the time during the summer.

As a sample of experiences that the teacher/student groups had with monarch monitoring, project staff reported on the monitoring activity conducted by Group 1.

> *Of the seven sites chosen by the nine teachers, six sites were monitored weekly after the summer institute at least four times. One site was monitored once. Four of the sites were monitored continuously until there was nothing left to monitor. In Texas, it was especially hard to monitor in the 95-100 degree heat, but the two Texas teams did it. For some teams, it was hard to find a site to monitor or their site was flooded or mowed sometime during the summer. Some groups thought the monitoring was a lot of work. However, many students monitored every week, and some teams brought additional students or adults to help them.*

Teacher Feedback on Monarch Monitoring

Teacher institute evaluation surveys (See Table B1, Appendix B.)
Teachers in all five groups consistently gave high ratings (means of 4.88, 4.80, 4.80, 4.56, and 4.86, scale of 1 to 5 with 5 the highest) to how much the activity "learning about monitoring and censusing" taught them. Teachers in Groups 3, 4, and 5 also gave high ratings to how much the activity would affect their teaching (means of (5.00, 4.89, and 5.00, scale of 1 to 5 with 5 the highest). Groups 1 and 2 were a bit lower though still positive (means of 4.33 and 4.0) about how their teaching would be affected.

At the end of the first institute, teachers were asked how confident they were in their ability to monitor. In four of the five groups, most or all of the teachers said they felt confident, or they felt very comfortable in checking back if needed. Group 2 had their first week of institute in Texas and seemed a bit less confident though they felt they would be able to do it with practice after reviewing the materials they had been given.

Teachers were also asked whether the data they would collect would be useful and important. They all agreed that it would be important. It was clear that they believed their data would *"actually be used in a real experiment. It's a good feeling to know that this experiment wouldn't be possible without citizens like ourselves helping."* Many were happy that their data would be part of a database to draw from to protect monarchs and other species.

Case Studies (See Appendix D for 20 case studies in full)
Teachers who were interviewed were asked to describe their experiences with monitoring. A number of these case study teachers had problems completing the monitoring part of the project, though some persevered.

Time and timing were problems
Some teams had a problem with the timing or finding time. One team said that because they were so far north, and it wasn't until the *"first part of August that they got out, it kind of disappointed the kids"* when they found no *"evidence of any monarchs"* in their area.

One team felt pressed for time because they were also working on their group research project and busy with other summer commitments.

Tedious but science
For some, the activity was tedious, but they understood it was a good experience to do it. And in one case they learned something about monarchs that was not known before.

One teacher said monitoring *"set the discipline. It got us into the habit of doing something. It was hot. It was sweaty. The kids got bit by bugs. It was nutty sometimes. But we wanted to do that."*

A Texas teacher said the 15 students she recruited to help learned that *"some of this science bit is wear and tear, and you don't see anything." "If we don't come, then we can't say there wasn't anything here because we don't know, and then, now in the last three weeks, we have been finding*

eggs and caterpillars everywhere, and they are not supposed to be here right now." This happened two years in a row and the teacher and the students are asking the experts *"why?"*

Interest spread to the community

Sometimes, people from the community became interested in what teachers and students were doing. For example:

> *"Our state park puts out a little monthly newsletter, and it gives the information that we find and they take our pictures. Sometimes when we're out there, there'll be people walking through, wondering what we're doing with the measuring sticks. So we show other people how to look for larvae and milkweed and talk about the different kinds of plants and when it's in bloom and stuff. So we are trying to expand what we've learned for our entire community."*

Inspired to continue monitoring

Several of the teachers interviewed were continuing the monitoring. They were interested in collecting the data for themselves and for the University of Minnesota and in providing the experiences for their students.

> *"We have now completed our third year of monitoring and have seen our research team grow by leaps and bounds." "Monitoring in the Texas summer heat can be brutal, so it means getting up early in the morning on our monitoring days throughout the summer. That is true commitment from teenagers."*

> *"It was good experience for them to be able to get out in the field and learn to collect the data. It wasn't just the same people that had done the original project with me. And I have let my students know that I hope to continue this project for who-knows-how-long and I'm looking for volunteers every summer. So far, I have not been lacking in students." "I also am still keeping the data for myself, because it might be neat to see what happens to the monarch population if I can monitor for 10 or 15 years and have that data to go back to."*

Some teachers were using the monitoring activity as a way to give students a head start on gaining skills and collecting data for research projects. One teacher said she became frustrated in that there's never enough time during the school year *"to squeeze in all the things you would like to do."* In addition, because of the seasons in Minnesota, she could get the kids outside to do fieldwork only a little time in fall and maybe a little time in the spring. She took a group of 12 students and worked with them every week on a monitoring project, doing field biology out at a meadow site and then had them each develop their own research project. She worked with them over the school year as well, to continue to build these research projects.

One teacher from a year-round school began a field study during the intersession before school started in July. He had chosen the top 20 8th grade students – about a third of the class – to work with him on a field survey. He described further, *"And when the summer semester starts in July, we'll continue the field survey, hit the scientific method with the whole 7th and 8th grade – that's part of the curriculum. And then that will give them something to base their scientific research on for the rest of the year, whether it be in Earth Science, Life Science, or Physics, so that we understand the model.*

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V. Transfer to the Classroom

Goal of Transfer to the Classroom

The Monarch Monitoring Project was designed to enhance the capacity of middle and high school teachers to incorporate active research and field experiences into their classroom teaching. All activities of the project had the ultimate goal of increasing inquiry-based learning in classrooms.

Teachers developed specific goals and plans for implementing research and other practices in their classrooms, and project staff visited teachers' classrooms and provided support through e-mail and access to materials (monarch eggs, milkweed, etc).

Active research is defined as students involved in formulating questions and/or designing research protocol, collecting and interpreting data, and reporting results. Field experience is defined as classroom activities or field trips that are conducted outdoors with students.

Project Staff Feedback

Even though teachers found doing an actual research project of this magnitude hard to do with their classes, project staff felt teachers were taking bits and pieces of it into the classroom in ways that they never had before. Some teachers found it impossible spending a month on research projects like these, even when the science standards might say they should. Teachers tended to simplify and bring it down to a gradable, manageable type of project. Staff felt though that, because of this project, teachers were better qualified to know what they were leaving out, what should be there, what the ultimate prize was, and then they could scale it back to a manageable classroom project.

Teacher Feedback

General teacher feelings about impact on their teaching
On their evaluation forms at the end of their second week, teachers commented positively that the institutes would impact their teaching. Some teachers said they had already changed their teaching by the second institute (held in October for four groups). For some teachers, the institutes resulted in a "sort of" breakthrough:

> *"I feel confident I can use these techniques in the classroom."*
>
> *"This workshop has had more impact on my teaching style and techniques than any other learning experience I have ever had."*
>
> *"This project will impact my teaching for infinity plus one!"*
>
> *"This paradigm shift in teaching has been scary, as I change over my 'canned' lab activities to a more inquiry format."*

Levels of use of active research and field experiences

Teachers completed an initial written survey before the first institute to assess the level of their use of (1) active research projects and (2) field experiences in their classrooms before they began the Monarch Monitoring Project. They completed an identical follow-up written survey and/or were interviewed by telephone. These surveys plus the case studies of 20 of the teachers were used to assess project impact on levels of use of active research and field experiences.

Evaluators, with feedback from project staff, developed categories representing levels of use of active research and field experiences before and after the institutes were completed. There were 44 teachers who completed both institutes. There was insufficient information about one of these teachers to assign a level of use of active research and insufficient information about two teachers to assign a level of field experiences.

Teacher use of active research projects with classes by levels (43 teachers):

	# Teachers	Before the project	After the project
Level 1	8	Already doing active research as defined	More comfortable doing active research, changed how they did one or more procedures, and/or started using monarchs rather than some other organism.
Level 2	14	Almost doing active research	Doing active research
Level 3	9	Not doing active research	Doing active research
Level 4	3	Not doing active research	Almost doing active research
Level 5	9	Not doing active research	Not doing active research, but trying new activities learned during the institutes

Teacher use of field experiences with classes by levels (42 teachers):

	# Teachers	Before the project	After the project
Level 1	9	Already doing many field activities	Still doing many field activities
Level 2	4	Doing some field activities	Doing many field activities
Level 3	13	Doing some field activities	Still doing some field activities
Level 4	14	Doing no field activities	Doing some field activities
Level 5	2	Doing no field activities	Still doing no field activities

Below are descriptions of the levels of use of active research in classrooms. Field experiences were often part of an active research project. Some teachers were having students do very sophisticated active research inside the classroom but only doing a few field experiences outdoors. Therefore, describing the use of active research is the better indication of transfer to the classroom.

Level 1 uses of active research (8 teachers)
Level 1 defined: before the project, these teachers were already doing active research as defined but, after the project, were more comfortable doing active research, changed how they did one or more procedures, and/or started using monarchs rather than some other organism.

Those teachers who had participated in "Monarchs in the Classroom" before becoming part of this project were able to go further faster toward using research and field experiences with their students. Staff thought this project was kind of like "Monarchs 102" for those teachers. They were doing active research better because they had the second step. Several teachers had already been attempting active research in their classes in order to meet the requirements of Minnesota graduation standards or to have students do research projects for science fairs.

Level 1 teachers implemented class-generated research projects the fall immediately after their first summer institute. One teacher who had tried research projects in previous years said, "*This year went much better than the previous year, and I feel much more confident leading the research component, taking my classes through these research projects*"

Two team teachers who, prior to this project, had their students doing experiments with other organisms in order to meet state graduation standards, switched completely to having all students work with monarchs. They had milkweed growing. They raised all their own larvae and built cages. They did not wait to get into it slowly. Another teacher said that this was her approach too, "*Either I'm going to do it, or I'm not going to do it. And I just uprooted my classroom.*"

These teachers also said they seldom used the experiments from the textbook or the lab book. One said, "*With the lab book pages, students would see the list of materials, see the steps, follow step by step, and not do any thinking until they get all the way done with the lab and then have to answer two or three critical thinking questions.* Instead, she will give them a problem, have them brainstorm in groups of four what materials they are going to need, what steps they are going to do, what kind of data they are going to collect, and how those data tables are going to look. Then after 15-20 minutes, they pull that together as a class, take ideas from everybody, then they go ahead and do the lab. She said, "*So this way they are thinking from the time they set up the problem until the time it's done.*"

Level 2 uses of active research (14 teachers)
Level 2 defined: before the project, these teachers were almost doing active research as defined and, after the project, were doing active research as defined.

In the pre-institute survey, Level 2 teachers sometimes gave examples of activities they were doing that they believed to be "active research" though their description did not match the definition of active research given them in the survey. After the project, they understood the definition, and as

one teacher said, *"I thought I was doing active research with my students, but I was only partly there."*

Several Level 2 teachers said that this project enabled them to do what they believed they should be doing and what they wanted to do.

> *"That was our philosophy to begin with [*referencing using the scientific method*]. What we've gotten are the techniques to use to implement that philosophy that we all wanted to be doing. Learning the techniques to work with the students has been very beneficial and has helped us to put in our philosophy of teaching – doing active research and getting out in the field – just given us more reasons to be there."*

> *"What [monarch training] helped me do was to focus. I always felt I wasn't quite accomplishing what I wanted to. We'd go out, it was cool, and we were collecting some stuff. I was showing them how to test water, but I wasn't coming up with an answer to things. And this helped me focus and organize the units, if that makes sense. The techniques they used to set up the research questions really helped."*

Most teachers who had been teaching students the scientific method before the project were very directive, giving students guidelines and even giving them questions from which to choose. One teacher said, *"Before, I'd always been very structured and gave kids a guideline and said, here's an example of topics, choose one; here's the structure I want you to use, and here's an example of what your end product should be. I would say, 'Here's your objective. Here's what it looks like. Go out and do something just like what I've done.'"*

For some teachers at this level, giving up control was a big leap.

> *"It is always kind of tough when you commit to such open-ended experiences. It's kind of like jumping into the deep end of the swimming pool."*

> *"At first it was hard because I am what you would consider a very controlling teacher – strong discipline, and it's kind of my way or the highway."*

One teacher's goal was to get living organisms into her Biology I class because she didn't feel she was doing enough at that level. After the project, she said, *"I can't imagine teaching Biology I without it now that I've started it. This is something that I plan on continuing for as long as I can."*

<u>Level 3 uses of active research (9 teachers)</u>

Level 3 defined: Before the project, these teachers were not doing active research, but, after the project, they were doing active research as defined.

Though level 3 teachers had not been having their students do active research as defined, most wanted to learn techniques and have their students actually use the scientific method and to do science inquiry. For example,

"Before I participated in the Monarch Monitoring Project, my students did little active research. I am now continually looking for ways to more fully engage my students in scientific research."

"I've had a hands-on philosophy, but I didn't have practical ways to apply that philosophy. I found that I would get very frustrated because even though my philosophy was this, I could never figure out how to implement it in the classroom in an effective way." "So it gave me the tools that I needed to bring my actual teaching practices more in line with my philosophy, and it's not as hard as I imagined it to be. The more that I use it, the easier it gets. I'm not so overwhelmed and scared off by the whole thing."

One teacher had been assigned to teach an advanced biology class in which students were required to do independent research projects. This project helped make him comfortable teaching this class. He said, *"I feel more comfortable tackling some of those questions – those research questions, and then setting up some kind of research protocol to answer those questions, after being at the institute and working with those students so closely."*

He also did a field study in another class. He said, *"As part of an ecology unit, I've written a field study as part of the new state graduation rule, guidelines and standards, and the field study they are currently doing is trying to ascertain and measure the biodiversity of a couple of different eco-systems and make some comparison. I feel like my experiences in the institute have helped that out quite a bit in planning that field study."*

Several teachers reached level three by the second year after the project. One teacher was able during the first year to have students do some pieces of a research project – observing, forming hypotheses, and thinking about design of an experiment, but it wasn't until the second year that she took students through all the steps of an experiment. She said, *"Last year we didn't get to do the experiment with the kids, designing the monarch questions, using the caterpillars, and so on. This year the kids are actually going to take their questions and design their experiment."*

During the first year after the institutes, one teacher had some monarchs in the greenhouse for students to learn about, but it was not until the second year – after being an instructor for Groups 2 and 3 and having one of the former project staff become his student teacher that year – that he fully implemented the inquiry method. *"Last year, with the biology classes, the amount of research-based stuff was nil. I didn't have it together yet?" "It's really jelled, and it's really come together. As I built my own knowledge base on how to do the research and have gotten more confidence in that, I've been able to find the applications, but I couldn't go right from the first year that I did it into doing it with my full classroom. I just didn't have the processing time to feel I could do that."*

Several said that every year they try more and get better at inquiry-based science. One teacher said she always asks herself whether there is a way to *"tweak some [units] to make them more inquiry-based, more hands-on for the kids, get less teacher stuff?"* She feels that every year, she's gotten a little bit better at that. She found she uses *"less and less notes and less and less worksheets, and more hands-on stuff each year rather than standing up there and writing on the overhead?"*

Level 4 uses of active research (3 teachers)
Level 4 defined: Before the project, these teachers were not doing active research, and after the project, teachers were almost doing active research.

Teachers at level four were trying procedures they had learned but were still struggling with full implementation of active research or were just starting to have students do some field work.

One teacher said, *"I'm much more open to doing open investigations with the students, where most of the labs that are presented to us in our curriculum are labs that the question, the procedure have already been established. . . . I really am working towards getting all my students to do their own investigation."*

One teacher had all her Environmental Science and Biology students raise 5-6 monarchs. After doing observation and journaling, the butterflies were released in September. She thought she would be more organized next year and be able to fully implement the active research processes.

Level 5 uses of active research (9 teachers)
Level 5 defined: before the project, these teachers were not doing active research as defined, and, after the project, were still not doing active research but were trying new activities learned during the institutes.

Even at this lowest level, teachers were not unchanged by the project experiences. Some were trying some things, but some were overwhelmed. In addition, two were teaching math and five were teaching science subjects where they were not yet using the procedures they had learned.

One teacher added some fieldwork to his classes and found it was successful. *"The 8th graders went out and collected insects and then were able to find the orders. That was something that we did at Wilder, and they became very good at it. That was the first time I had ever done that. I had always heard about it, I've always read about it, but to actually DO it was kind of fun. I became fun for the kids."*

Even when teaching another subject, teachers could refer to what they had done with monarchs. One said, *"In my current classes, chemistry especially, we do experiments, and I refer quite often to that very valuable field experience working with the researchers. I tell them the parallels, although it's pretty lose between chemistry and biology."*

Teachers in later groups were still in their first year and were hoping to do more next year. One said, *"I feel like I'll be able to do more because I won't be under the strain of other things. I will be able to take something and focus with it. I'm a little more experienced with it. I have a little more knowledge about what we're doing. So your first year is trial and error, and you don't really know what you're doing yourself."*

Another said, *"If I can just take one idea and have the kids do something as a class, where we just have one problem, and we just do it all together and do more cooperative learning situations . . . That's what I would probably have to do. It could not be an ongoing thing the whole school year or*

anything magnificent. It would just have to be some little things that we can do together as a class, to get them going in the right direction."

Use of new knowledge and skills

Teachers at all levels of use of active research and field experiences reported they were using new knowledge, skills, and teaching techniques they learned during the institutes.

Science content knowledge

One teacher was attracted to the project because she hoped it would strengthen her biology background. She said, *"This was a real introduction to bugs, insects, that sort of thing, that I was able to apply to curriculum. We've changed the way we teach, and in the middle school grades you teach some of ALL of it. So that was a very helpful thing to have a biology component that I could bring in."*

Another teacher mentioned she was able to explain independent and dependent variables – "*one thing that I did this year that I have never done before." "I could also give the null hypothesis which I didn't know before I took the class."*

Statistical procedures

Several teachers mentioned that they had not used statistical procedures with their science students before this project, and they found statistics an important addition to students' research projects.

> *"I had a lot better understanding of how to apply statistics to data that's been collected. And so, with all my students, I required that they run either chi-square or a t-test on all their data for their science fair projects. And that was huge. That really made a difference. In fact, our school . . . won the best school award, and I have no doubt it was in large part because every student ran statistical analyses over their data, and that verified or didn't verify what their findings were."*

One teacher considered these mathematical procedures *"difficult and abstract,"* but he was trying them with his classes and said, *"It's going pretty well."*

New skills in analyzing data

As a result of the training in the use of the Excel program, one teacher found it facilitated students' ability to accurately and efficiently analyze data for a variety of research projects. She said, *"I have switched over from ClarisWorks with my students."*

One teacher said she had overlooked the analysis piece when teaching scientific method. She said, "*That's something I would continue to expand upon. The statistical analysis is something really important. It's a great way to integrate math into science, and I would like to do a lot more with it."* She said she needed to spend a lot more time with it looking at all the different ways you can take the data and use them. She added, *"It's hard because that's always at the end of the process and that's when we're scrambling for time. And yet it's important to stop and give kids a long time to think about what they have and what questions they can answer from it."*

Another teacher identified analysis as one of the biggest problems that teachers who require science fair projects have. She said it usually is *"Okay, now you have the data, what do you do with it?"* She felt, *"Kids come up with ideas, or I come up with ideas, and they do a fairly decent job of controlling the variables and collecting the data, but then what do you do with it?"* She felt the October institute addressed that problem very well.

One teacher learned that an experiment does not have to have noticeable or statistically significant results. She said, *"When you look at scientific research, sometimes you're not going to get a noticeable change. And so this year, as we're doing science projects, even if a kid tests something where the results aren't real slap-you-in-the-face kind of results, that's going to be okay, and we're going to teach them why that's okay."*

New teaching skills

One teacher described how the project changed the way she approached field experiences. *"Now when I go outside, . . . one of them will say, 'what is this?' And I'll look over there, and maybe it's a gall or maybe it's a spittlebug. So we'll talk about it, and I think I've learned patience, because instead of just telling them what it is, I get them to inquire and try to figure it out."*

Spread to more teachers

Though not a focus of this project, there was evidence of outreach to teachers beyond those in the project.

Spread to teachers through students

In one district, the elementary teachers became interested in butterflies when junior high school students made presentations in their elementary classrooms. Sometimes junior high school students' parents were teachers at the elementary level, and they got butterflies for their classrooms through their children. With 40 extra larvae, a junior high teacher handed them out to students to take home to their parents to bring into their classrooms. That project teacher was available to help, *"It's kind of an open channel. They know if they have any questions, or they want any things, to let me know."*

One teacher predicted she could have an impact on teachers in her building by her students spreading the word. Indeed, a colleague said to her, *"[My students] are all mad that we're not doing it, so maybe you need to be telling me how to do that, and let's be ordering two sets of what you're doing."*

Encourage colleagues to attend monarch training

Some teachers tried to get other teachers to attend later institutes or the Monarchs in the Classroom program. One teacher did get two other teachers from her school to attend the monarch training. One teacher wrote a grant so that two third-grade teachers from the two elementary schools in his district could attend the Minnesota Science Teachers Association (MnSTA) annual meeting and join MnSTA. The two teachers also attended the Monarchs in the Classroom training.

Informal spreading
Teachers across one district shared resources. The high school grew milkweed in its greenhouse and the middle school teacher from this project had plenty of eggs to share. This teacher informally mentors a number of teachers who have heard about what she is doing. They contact her and check out materials, and she answers their questions.

Through team teaching
One project teacher began team teaching two years after she participated in this project. *"All of us who are teaching 7th grade science now team teach. We removed the portable wall that separated our classrooms and so there are three of us. The two other 7th grade teachers with whom I now am teaming have never been through our Monarchs in the Classroom class. So, while I'm not formally mentoring anybody, I was essentially giving them lessons and private instruction in how to do everything. And now they are experts."*

Presentations at science teachers' meetings
One teacher had been making presentations at meetings of science teachers for a number of years and was looking forward to presenting what she learned through the Monarch Monitoring project.

Another teacher and her students went to a cooperative education group, where a lot of teachers come together, to present their research.

Through science departments at their school or district
One participant chaired his school district's science curriculum review committee that was looking at their K-12 science program. He shared what he *"picked up at the institute"* and said it helped them *"align their curriculum, and scope and sequence it, and align it with the grad rule and the national science standards."*

One teacher was pleased that the other biology teachers in his department adopted the insect biodiversity field study to meet the field study requirement of the graduation standards. He hoped that when the department debriefed how it went that he would be able to tell them the advantages of adopting some of the other methods he was using from this project. He felt that graduation standards requirements were opening his colleagues up to trying some new things.

One teacher was able to present the whole monarch project and the approach to this project at a district workshop. She said, *"I was asked to share what our research was and what I've been doing in my classroom for the past few years. I had lots of questions from teachers, not only our other junior high teachers but also some of the high school teachers as well, at that workshop."* She found teachers in the district were interested in finding out how to work with monarchs and what the pitfalls might be.

Spread to elementary teachers
One teacher volunteered to give presentations at elementary schools in his and other districts. He could do it from his greenhouse where he had a TV and speakerphones. He developed materials for the teachers to use in advance of the presentation. He said, *"What I really want to do is to help elementary teachers find developmentally appropriate material to do inquiry. They're so loaded*

with the diversity of things they need to be able to do, if I can help them out with just this one piece, maybe that will be worthwhile."
A teacher from a K-12 school shared with her colleagues. "I shared a lot of my monarch materials with elementary program students and teachers in summer school. They raised their own monarchs and were real excited about the project. I expect to expand the monarch unit for elementary teachers for the upcoming summer."

Involving other disciplines in the school
One teacher found it easy to work with teachers from other disciplines at her middle school. She reported, *"The art teacher works with me in the fall and does monarch artwork. The math teacher, if I need help with graphing or I need kids to be aware of that, she does that. Our technology person does the Journey North with my students so I'm not taking out of my class time to do that. I set up everything, but they get to use the computers to do that. We have a nice team thing going here which is very helpful in doing anything like this. If I need extra time, I can do some negotiating with class time, if I need to be outside and things like that.'*

Curriculum adjustments by teachers
Most teachers needed to adjust their science curriculum in order to incorporate work with monarchs and/or scientific research.

Using monarchs to teach the regular curriculum
In order to study monarchs when they were available, one teacher reorganized the seventh grade curriculum so that they studied ecology first, and then went into the study of plants and animals. She also used monarchs to teach science techniques in a more engaging way. She said, *"When you're just starting off on your study of measuring, rather than measuring the tabletop and the text book and those things, we measure caterpillars and monarch wings and find the mass of the monarch, so it just makes science come alive for the kids, and it's much more interesting."* She added that the school was focusing on graphing and making tables and charts. She felt, *"All of these data we're collecting really [work with] that type of lesson, and I think the kids have something real that they've enjoyed that they can use to practice these skills."*

One teacher had been able to incorporate the monarchs into much of what they do in her district. They have what they call a discover sequence, and every three weeks they have to cover a certain topic. She said, *"I've been able to cover those topics in totally different ways. How we present the material is totally up to us. We have complete freedom. So that's what I've done. Growth and development – well, hello! Here's this butterfly. Growth and development is what's occurring. And hormones, we've talked about hormones. We've talked about metabolism. This poor little critter has just given us everything we really need to teach everything."*

Modifying curriculum to get everything in
Two other teachers adjusted their fall curriculum to build it around student experiments with the monarchs. *"We cut out a full chapter on characteristics of living things, but we tried to emphasize as we worked with the monarchs that every organism has certain needs that have to be met and what the characteristics of life are and that sort of thing, work through it that way. So we weren't just giving it lip service, but were literally covering it indirectly while working with the monarchs."*

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About their curriculum, the other teacher said, *"It's tough to try and cover the rest of our curriculum now, and so, that will be our goal next year – to figure out how we can modify it some more so that we can get everything else in."*

Tying the curriculum together with monarchs

And then as far as her curriculum was concerned, a teacher found it had given her *"a focal point—something to tie the entire year together." "We start out with the monarchs, and we use the monarchs for all the beginning of the year stuff like the needs of life and what makes a living thing and the scientific method and experimentation and ethics and handling and care for it and measurement—all those beginning-of-the-year stuff that you cover in science."*

"Then throughout the year, I bring it back up. Like when we're talking about genetics, we bring in some monarch stuff with genetics. When we're talking about the different kingdoms, we bring up the insect order, and we bring back the monarchs. How many legs did the monarch have? How many wings did the monarch have? All these things. And it gives them a focal point, again, to remember, 'okay, well here are the parts of the bug because this is what my monarch had.'" "Then, at the end of the year when we had the ecology, it gives them something that's already touched their lives, to say, 'why should I care about what happens in Mexico to these forests? Oh, because the monarchs. Why should I care if people are planting milkweed in their garden? Why should I care about genetically-altered corn? All those sorts of things.

Relating to world issues

One teacher talked about finding that there were many times that monarchs related to recent issues in the news. She said, *"Speaking of genetically-altered corn, it's given me an opportunity to tie things in that are currently happening. There's a lot in the news, the last few years, on this whole BT corn and the monarchs and their habitat and all that stuff. And so it's added that piece to my curriculum, where the kids are looking more in the newspaper and listening to the news. And they hear things that we're studying in class and they get excited about the everyday application about what they're learning in science.*

Incorporating University of Minnesota developed curriculum

A number of teachers were using materials from the middle school monarch curriculum developed at the University, particularly the sheets on "how to ask a testable question," "making a hypothesis," and "designing an experiment." A teacher said it was the best curriculum she had seen to use in teaching "How to make a question?"

Assisting with implementation of national and state standards

Teachers mentioned that the project was helpful, and even crucial, in their understanding and implementation of national science standards and state graduation standards. One teacher became interested in the Monarch Monitoring Institutes to find a good active study to include in their graduation rule requirements and to continue some work with monarchs started in his district's elementary school. He wrote in his application, *"It sounds exactly like the type of inquiry experience I have been hoping to find."*

One teacher said, *I'm working with a committee for implementing the national science standards and inquiry learning, and we really didn't have a real good idea about how you go about doing this."*

Another teacher noted that the focus on standards was making the scientific method more important than it was before. *"This fits right in."*

"As a matter of fact, the standards and the monarch unit came into my life at the same time. Where other teachers were overwhelmed at having to re-write their entire curriculum to fit the standards, once I implemented the monarch curriculum and adjusted for that, the standards were there. . . . I can get out most of my standards right there at the beginning of the year because they're all covered in that monarch unit – the whole inquiry standard, the direct observation standard. "

Inherent problems and roadblocks for using monarchs in the classroom

Amount of curriculum

One teacher believed that the monarch unit fit in the curriculum requirements, but there were still a lot of other science knowledge requirements she still had to complete. *"We're supposed to cover X amount of curriculum and doing active research fits into that. But it still takes time, and so then you're trying to get everything in. And I don't have the answer to that one because it seems like we're always asked to teach more and yet never given more time, and they never want to take anything out. So that, sometimes, can be a problem."*

Several teachers talked about reconciling themselves to covering fewer chapters in the textbook. One teacher concluded that her students were going to "*know what they do well"* and *"have some skills."* She felt her students can "*use their brains and do science*" while other students have been *"shoved a bunch of information that they have forgotten." "I'm not covering as much ground, but the students are learning more." "I don't even want to tell [my colleagues] how far behind I am."*

Managing the numbers of students

Managing the numbers and behavior of students was often mentioned as a problem. One teacher said, "*You can't just decide to take 30 kids outside to try to catch butterflies to tag and release."* Another said, *"It depends on the make up of your classes. If you get certain kids spinning off each other, sometimes it's difficult."* Another teacher said, "*Some kids don't care . . . the way I get around the unmotivated kids not caring is to get a core of kids who do care and make them project leaders.* One teacher was concerned about having an entire class visit a site because *"they trample it."*

It is a lot of work!

Teachers agreed there was more work involved in providing and caring for the materials needed for conducting experiments with monarchs. One teacher said some people probably would never adopt what she has been doing because *"the time I spend here is enormous."*

A teacher described trying to teach a lesson while butterflies were coming out. *"Okay, that day we have 30 butterflies coming out. All the butterflies need to be weighed and measured. When can I*

find time for this assessment (metric measurement) that everybody has to do, and it takes the whole period. There's a study hall, and I have kids come in, and they help do that, but really, it kind of falls on me often. Sometimes these butterflies come out over the weekend, so I have to go in on the weekend to check for any new emerging butterflies."

One teacher spent the time when students were supposed to be doing silent reading, scrambling to get all the cages cleaned for the long weekend coming up, helping a student dissect a chrysalis that had died, and watching students cauterize the gold dots off a chrysalis. About the dissecting and cauterizing, she said, *"That was awesome."* After all that, she said, *"It all works. For some reason, it all works. It's very hectic in here sometimes."*

Beyond Butterflies

There was a question about whether teachers would be able to transfer what they were doing with monarchs to doing research with other organisms and materials. However, there were many examples of teachers doing research with other materials and organisms. But what they did with this project secured the skill and confidence.

A teacher felt this experience *"gets you excited to teach science and gets you prepared to use the scientific method as an inquiry tool for everything because you can see it works for any experiment you ever want to do."*

We also did a water research project. It's kind of the same process [referring to monarch study] *but just a different subject. So the students are going out and we did a bunch of stuff with water and stream because we live on the St. Croix River. But then, instead of just studying how rivers work, the final thing was that they designed their own questions."*

Several teachers from the project collaborated to develop a field study for their student graduation rule requirements. They needed something that was available earlier in the spring than milkweed and monarchs. These teachers planned a joint monitoring project for spring 2001 – monitoring the nematodes that are in the soil on the grounds around their school buildings. One teacher said, *"I feel much more qualified to do that, having done our monarch monitoring and our milkweed monitoring."*

One teacher, once he started doing active research with his students, saw he could have students work with many other organisms or materials of their choice. He said, *"I see it as a bigger picture. I love monarchs; they are a great organism to work with. But right now in the state of Minnesota, the wolves are a huge issue. The monarch is, too, in terms of you're getting media attention so that kids go, 'I did see something about that in the paper or on the news.' So I think we need to try to focus on some of those things that are naturally of interest."*

One teacher could now expand what the students could do with field studies. She had not learned many field study techniques before this project; now she had more ways to study ecology and diversity of an eco-system. She added a number of new research projects to her classes this past year: determining what increases the rate of composting, determining the effect of fertilizer on algae/pond life, and determining the effects of cross-pollination on plants. For each of these

research topics, she said, "*The students chose what project they wanted to investigate, they designed the experiment, and they carried it out.*"

A teacher was planning field experiences for her aquatic biology class. "*This spring, we will do a fresh water, open-ended kind of study where we will be monitoring a stream. In the fall, we took a trip down to the coast, and we did a waterfall we'd been monitoring. We asked questions at different locations, talked about things like salinity and dissolved oxygen and used some of the techniques for questioning and hypothesizing that I'd learned with the Monarch Project.*"
One teacher planned to wrap-up the school year with an ecology conservation unit; main focus would be to look at the various habitats of living things. Observation would be the process she emphasized with students. "*I have all kids do mostly observations and journaling of activities.*"

A teacher teamed with the calculus teacher to add active research to the winter environmental research unit. She stated, "*One of the things that came out of this was that we did a winter research project where we had students go out and design questions to research in the winter.*"

Other changes or benefits

Planting a butterfly garden at school
One teacher was putting in a butterfly garden at the school because they did not have any milkweed right on school property. "*We have this SNAP area, and we have all these really neat things, but we don't have any milkweed. So we're putting in a butterfly garden and we're going to try a couple different varieties of milkweed, and hopefully, be able to attract some monarchs to our site.*"

Better science fair judges
An additional benefit of the project was that teachers would be better science fair judges. Teachers felt this was an important part of being a science teacher. "*Not only am I a better teacher, but when I'm asked to judge science fair projects, I can go and judge a science fair project, and I can understand much more fully the strengths and weaknesses of that project. And I'm able to guide students by asking them questions. You always have these 10, 15-minute shots where you're at a science fair, and you're interviewing future scientists, and if you can help them understand what's good and what could be better about their project, I think you're really doing them a service.*"

Traveling to Mexico
In winter 1997, one teacher and four of her students traveled to Mexico to see the overwintering colonies. "*There are a dozen locations the size of a football field that they go to,*" she said. "*It's just awesome to see.*" The next year, 12 students went.

After school science clubs
A big project that was new in one school was their Butterfly Club. It started "*out as a Monarch Club because these kids just couldn't get enough time in, feeding the butterflies and being in the tent. So we started this Monarch Club. And it was very, very intense — once a week on Wednesday nights in the fall.*"

One teacher started an after-school science club modeled after inquiry-based investigations done at the monarch institute. She spent a great deal of time there in the fall with her students studying ecological relationships in a field close by.

Involved in the community

One teacher joined boards for Camp Courage for their environmental education program, Friends of the Boundary Waters education committee, Wildlife Science Center in Forest Lake board of directors, and the International Wolf Center to help these organizations develop activities and resources for teachers.

VI. Student Participation

Description of the student participation in the project
Each teacher participating in the project selected two students to take part in the institutes and help with the monitoring and team-generated research projects. Project staff hoped students would also help their teacher back at their schools.

Why have students at the institutes?
Having students be part of this project was an expensive piece, so there were many questions about the value of having the students. Teachers agreed the project was greatly enhanced by having students there.

To be able to model teaching
Project staff could model for teachers how to be less directive with students. One project staff member explained, *"When we would work with them in groups, we would try not to answer their questions or answer their questions with questions and not just give them the answer. And we tried to do a lot of modeling of what we were trying to teach. And some of them didn't get it, but some of them did. It would have been hard for them to get it unless they could see us interacting with their students. And in many cases, when we were working in groups, and some teachers would start directing the kids too much, I would sort of talk over them, without saying, 'okay, this is what you should do,' I would try to turn things around and try to get the students thinking and sometimes the teachers got it. Sometimes they just walked away."*

For teachers to see how students respond
Teachers agreed that students should be part of the project so that they could observe them. One teacher said, *"I have come to know more about students and monarchs than I ever anticipated."* She said, *"I probably learned as much from watching those kids and working with those kids, as I did with just doing the stuff that was there."*

It was important to have students attend the institutes *"because that gave you an idea of how students react and the level of your presentation and the degree of their understanding of various experiences."*

Higher expectations of students
Project staff found that teachers underestimated what students were capable of doing. Staff could demonstrate that students could do these activities, such as run statistics. A staff member reported, *"One of the most interesting things in this whole workshop was their reaction to us trying to teach 7th and 8th graders to do basic statistical tests – t-test and chi-square, two of the very simplest tests. I think some of the teachers were math phobic, so seeing an equation that was kind of long really scared the teachers. Immediately their hackles went up, and they said 'the kids are never going to be able to do this.' But the students could do it right away, and in a lot of cases, when they were learning this, it was the students helping the teachers because they knew how to use the calculators,*

and they knew some of the symbols, like a sum symbol. Some of them did go back and do some chi-squares in their classrooms and, wow, they were really excited and empowered."

Several teachers said they have raised their expectations for what students can do.

> *"I can honestly tell you that there were a lot of things I thought were out of reach and just too overwhelming to do. I have seen that kids are capable, sometimes, of a lot more than we think they are."*
>
> *"I began to see how the students learn. And I began to see how far you could push them." "I can put a lot more ON the students than I thought. I can demand a lot more than I had been demanding."*

Teachers also found that they could expect more of students when teachers did a better job of teaching. One said, *"I expect more of the students because I know that I taught it better, and so when they turn in lab reports, they get it back sometimes because I expect more. I know more about it now, how to teach it, what's a good conclusion, and what's good data. So it makes the students better scientists."*

Students come back to help their teachers

Many of the students who attended the institutes helped their teachers when they were back in school. *"They buy into it, and they get excited about it, and they come back and they become the teachers."*

Teachers found the students were effective teachers.

> *"The students make really great ambassadors." "When they come back in the classroom, the students don't have to just hear it from me. They can hear it from their peers, and sometimes they can explain things a whole lot better than I can." This was "really beneficial."*
>
> *"They did just an outstanding job. They were there to help with the butterflies – help me explain things to the students. There was actually one time when I got called out of my room, and I had my two students continue on with the class because we were talking about the monarchs and about their lifecycle. I had the girls actually teach the class when I got called out."*
>
> *"The two eighth graders have been phenomenal. They helped with the prairie day and took grade seven students out to a field project."*

The students were effective in involving other students at their schools. *"They're very proud of their knowledge. They are big campaigners for students to get involved with this. They're going to be seniors next year and so next week, they want to have a lunch meeting with a couple of people that they think might be good to work next year to be their replacements on the research team."*

Students taught what they learned outside their school as well. At one school, *"The two students lead a session during the summer (five weeks at Augsburg) for GEMS – Girls in Engineering, Mathematics, and Science." "They will also lead a community education workshop to expand the base in middle school for 12 students." "They will mentor the third grade students in the three elementary schools."*

Valuable for individual students who went

Teachers found that there were benefits for the individual students who attended the institutes.

> *"The two students I had with me have benefited personally because they have a lot of confidence now. Both of them were high at-risk students. I purposely target those kinds of kids probably a lot."*
>
> *"The two students who went with me both said because of the experience they had, they're both looking at careers in science. So it opens more doors and more opportunities in science-related areas, even if it's not necessarily research or monarchs."*
>
> *"The kids liked it because it set them apart . . . they were doing a research project, and they knew they were doing REAL RESEARCH. And so, they were scientists and the whole school knew it. And some of the classes would come up and the teachers would say, 'Can we walk through the lab and see what you're doing and have you explain it to us?' And the kids had their white jackets on and their lab stuff on, and they would say, 'Yeah.' And they really shone."*

A teacher from an urban school took advantage of University of Minnesota staff by taking students on a field trip to the university. She said, *"I've been able to take some students and get them a little bit more familiar with seeing the behind-the-scenes stuff at the university so that they know what they might anticipate, because they've never had an opportunity to be over there."*

One teacher reported on a change of attitude about bugs by one of her female students. *" I have one student who participated in the monarch institute that I would call my glamour girl of the class. She was real prissy and simply hated bugs. By the end of the Texas trip she was picking up all kinds of bugs with her hands. And she actually asked her mom if she could have a pair of hiking boots and gear to do field work."*

Impact on Students in the Classroom

Students were part of something real

Many teachers related that being part of real research captivated them and their students. All of one teacher's students were involved each year in tagging and releasing of a couple hundred monarchs. She said, *"They feel like they are part of an international research project. One of our monarchs was found in the Mexican colonies."*

The students felt that they were "*part of something bigger.*" They were learning from those who were most expert in the field, i.e., real-world scientists.

When the students' larvae emerged as butterflies, they tagged them, released them, and sent the data to Monarch Watch. "*The students felt like a small part of a big picture when they found out that their data would be sent to Monarch Watch. We were then able to discuss how this tied to the work that Dr. Oberhauser is doing at the University of Minnesota, and how I was a part of that. That experience enabled me to explain to my students what being a field biologist is all about. I know that some of my enthusiasm carried over to them – judging by the critters they brought back from their milkweed hunting.*"

One Minnesota teacher's classes were connected to scientists from Texas. The students helped prepare 150 monarchs to send to them for research. "*We had a role in getting butterflies for the scientists and that's pretty exciting for [the students].*"

Both students and teachers liked the fact that some of the ideas they come up with were new and never researched before. They could really make a contribution that was important. One teacher thought this was another way that she changed her approach to teaching. She said, "*I always had a lot of faith in kids, but I've only been teaching middle school for three years, and I think there's just some great potential there for them to really be contributing in a significant way, and I want them to see that they can do that.*'

One teacher said, "*It is exciting to know that the data we are collecting is adding meaningful information to the scientific community's understanding of monarch biology.*" She added, "*My students are amazed at all of the interesting things they are finding out just by consistently doing simple scientific field research. The more they find out, the more questions they have and the more they want to do.*"

Student engagement in the classroom

Students transfer learning and remember better

One teacher was surprised at how well her students "*transferred what they learned from the experiments we were doing in class to that new experiment* (on the test*) that we had never talked about in class.*" "*They were able to with roughly, 89 or 90% accuracy [on a test], tell me the independent and dependent variables, make a hypothesis, and to design an experiment, and it was something they had never seen before.*"

It just makes them better problem solvers, makes them better thinkers, and they remember the results better because they've done the entire thing,"

Kids more excited and engaged

Many teachers talked about how much more interested and engaged their students were when doing active research and field work.

"You just feel so much more energized and enthusiastic . . . I'm just eaten up with it right now and the kids are, too. They love it."

"Class participation hasn't been better. . . . I think they're just enjoying it."

"Once you get your feet into it, it does show you how much it helps to have kids get that actively involved." "Overall, anything we did with the monarchs, I got far better than average participation in it."

"I am continually amazed at how on task my students are when they are engaged in collecting data on their monarchs. I could probably leave the room and they would continue to be completely involved with their critters. Students are excited to come to science class and even want to continue their data collecting on weekends."

Teachers saw demonstrated how important it was for students to buy in to what they were doing.

"Students have a better stake in the experiment. . . . They are a lot more excited about doing the lab."

"Kids, these days, are just dying for something to believe in and take ownership in, and this has given a lot of them something fun to do that with."

"What this butterfly project has taught me is the importance of kids developing their own questions, whether they're developing them for science fair or whether they're developing them for specific areas of study that we're doing in 6th or 8th grade." She had seen that it was exciting to the kids, *"especially in middle school,"* and they need to develop their own questions rather than, as she said, *"have me telling them what the question is right off the bat." "They need to explore and have real ownership in what they do."*

Student behavior was better

"When we're hands-on – when we're doing this, it's a lot easier for me to see that I have fewer discipline problems; I have more on-task behavior. It's kind of a no-brainer in that respect."

Special education students do better

A teacher was excited about a class she had that was about 80% special education. She said, *"Those kids are really into it. I have another certified teacher who spends a great deal of time in the room with me, and she's commented to me several times how this has really gotten the kids' attention, and that they're talking about it down in the special ed room. An.. anything like that that they'll talk about – I call them 'carrots' – are great ways to kind of hook the kids into learning."*

Science Fair participation

The Monarch Fair at the Science Museum of Minnesota was an important motivator for teachers and students. It was an incentive for them to have their kids to do research projects. The Monarch Fair was designed as a place where the students could bring and show off their projects. It also

motivated the teacher/student teams to finish their team-generated research project write-ups. One teacher said her students had a "*memorable experience sharing their research findings with others.*"

There was also evidence that project students were successful when participating in science fairs. Below are some examples of science fair participation:

The first year after she attended the institutes, three of one teacher's five class projects were good enough to take to the Monarch Fair at the Science Museum of Minnesota.

One Texas teacher's three students, who worked on the team-generated research project, won their district science fair competition with their project and went on to the next level.

During the second year after the institutes, one teacher continued working with students in a monarch team that met periodically after school and on weekends. She reported, "*We have traveled to the Texas golf coast to monitor the butterflies down there. Earlier in the year the students on the team did independent projects and several of them are working to prepare those projects now for science fair, for the Junior Academy of Science and the Alamo Regional Science Fair.*"

"*They all went on to the state science fair this year and two of them went to Kansas City for the monarch population dynamic meeting in May, which was very exciting for them.* "

Teachers from two different schools talked about starting local school science fairs.

This school year one teacher had four classes of students participate in the National Public Lands Day, where they did prairie restoration work.

VII. Parent and Community Involvement

Many teachers and their students did activities with monarchs that involved students in activities outside regular classes and involved parents and community.

Involving parents

Each fall, one teacher had about 30 parents at her Monarchs for Parents class. She spent about an hour telling them about monarchs and then about an hour talking about how to mentor their child in a science fair project. She said, *"At least a dozen of [their children] do science fair projects on monarchs."*

When students raised monarchs at home, their parents and whole family tend to get involved. One teacher said, "*This monarch stuff infiltrates homes like cold in wet weather. Parents come in asking questions about monarchs and about the research.*"

> *"One of the biggest, important points that I found out about this was that sometimes I got the whole family involved. Students took their caterpillar home to do the journaling. Parents called me up and said, 'I was helping the kid with it, and they had that little First Instar and something happened, I don't know what, but I know I probably destroyed it or stepped on it or whatever. Could we get another one? Or where can I get one or what can we do?' I had parents involved with that every day. They were just amazed at how much it grew and stuff like that. I tried to stress to them at open house where they can help and make sure that the students complete that journaling work. We got really, really good feedback from the parents."*
>
> *"Parent-teachers conferences in the fall were the most positive thing I'd every experienced. The parents were in awe. That's all they wanted to talk about at conferences. They didn't want to talk about their kids. It was just incredible, and our principal was just loving it. So it's been really good for our school."*
>
> One teacher found that because she did this project at the beginning of the year there was *"an immediate connection to the parents."* She said, *"I find I have better turnout to conferences and better parental support right off the bat because the parents get just as excited about the project, sometimes more excited than the kids themselves."*

Involving community

One Monarch Club involved two members of the community in developing a butterfly garden. After they released their monarchs in the fall, students wanted to keep their monarch club going so they searched for something to do and found it in developing a butterfly garden. One of the students had a mother who was a master gardener. "*She did a huge garden at one of the local elementary schools. And she said, 'what a nice project this would be, to put a butterfly garden in here at Willow Creek.*" By spring, the "*Butterfly Club planted little seeds and we've got a grow light out in the hall — 2-tiered, 4 trays in each tier. So it really holds a couple hundred plants. We're growing plants for our butterfly garden we're going to put in, hopefully in another month.*

We're raising the plants." "We're going to take up some sod. And the kids designed it and the shop teacher is going to help them build some benches, and it's going to be in the shape of a butterfly. I'm just delighted that this mother comes to all our Butterfly Club meetings now, and she helps the kids talk through what's good and what's not. And then she brings her intern master gardener with her, so it's nice to get community members involved in the school."

Teachers found many opportunities to share their monarch work with the community. For example: "*In the last few months, my students and I have been asked to informally share our research and the techniques of the monitoring program with staff and children at the River Legacy Nature Center, the Arlington Master Composters and the Arlington Garden Club. In addition, I have been asked to prepare an in-service on monarch monitoring and ecology for area teachers. Other venues could certainly include Girl Scout and Boy Scout troops, school ecology clubs, senior citizen groups and the University of Texas at Arlington entomology department.*

Spreading enthusiasm at the school

"Enthusiasm for monarchs is infectious. My students talk to everyone about monarchs. When we walk out to the field to monitor, students on campus ask about what we are doing and come out to help."

Sharing with community

"That enthusiasm spreads to neighbors who then call Lamar High School to ask about planting butterfly gardens in their yards. The ultimate ability to share our monarch enthusiasm came this summer when, because of our involvement in monarch research, one of my students and I were chosen to be the Grand Marshals of the Arlington, Texas, Fourth of July Parade attended by literally thousands of people."

Involving community with the school

One teacher in an urban school took 10 students to Mexico to see the monarch's final migratory destination. This was no small task. First, they needed district and school approval. Second, they needed substantial funding. And third, they needed moral support. They were able to get the entire school community to rally behind their fund raising efforts for the monarch trip. In fact, initially, the district denied them permission to go to Mexico. But a group of "parents" petitioned the district to rescind their decision and allow the students to go to Mexico during their spring break. The district eventually agreed. They raised their own funds. The students got an experience of a lifetime, i.e. to observe the monarchs final migratory rousting place. They agreed to prepare a slide presentation of their trip to be shown to all interested community members. Hence, the community could vicariously share the Mexico trip with students. "*The community is excited about monarchs. And they know about us going to Mexico. Parents call to tell us when they have seen monarchs; it has been a kind of bonding.*"

Covered by the news media
One teacher had a huge project over the summer. *"We had over 1,300 eggs and reared 700 monarchs. Teachers and students were stopping by, and we even had newspaper coverage."*

Another teacher shared much of what students learned about monarchs through newspaper articles, TV coverage, and Junior Academy Science Fair participation. Students had taught adults in the school community about monarchs, including presentations at the Audubon Society.

One teacher said she had not done as much to involve the community as she would have liked. *"We HAVE invited the community out for some of our monarch releases and the newspaper has come and taken a picture of that one year."*

"We have sent out the school newsletter including information on monarchs.

In yet another school, the local paper came out, followed the whole story, and did a big spread in the paper. There was a story on the local TV station. All through the year, the kids went out to different classes and talked about how the experience had changed them and the active research they had done and how they had had to write papers.

Teachers became the community's expert
One teacher said she had become the community "go-to" person on monarchs. She often received calls from community members asking questions about butterflies.

A teacher credited her participation in the monarch project and the media exposure she received for getting her name out in the community as someone who knows and is interested in ecological community projects. She said, *"With the contacts I'd made, we've gotten involved in eradication of exotic species. We were actually contacted by a community member to have students come out to Spring Bank, which is a local area where there's a lake and residents have cabins. We did eradication of Glossy Buckthorn out there. I guess the way they found out about me was through information that was in the paper, again stemming from the contacts I made while doing my monarch project."*

A third teacher said, *"Almost everybody in town knows, basically, that I have this interest and this love of monarchs, and that anytime anybody sees a monarch or has a question, I get phone calls at home. The monarchs aren't something I just do in the classroom. This is something I'm looking at all summer. People that know me know that whenever I see milkweed, I'm always looking for caterpillars. When I find them, I bring them home to raise them. I've actually got milkweed growing in my yard because I want to see if I'll get some eggs and caterpillars on it. So it's become a part of my life. It's not just used for one unit during the school year and then I forget about it. In fact, my husband and I were talking about a way we can get milkweed in our garden and get some butterflies in there and put a cage around it."*

"People are now always mailing me articles when they find information about the BT corn and how it's affecting the monarchs. People in the area who've seen my name in the paper, that I don't even know, send me information like this."

Beyond the classroom – additional funds
Two urban junior high school teachers applied for and received a grant for about $8000 to take some of their students to Mexico.

One teacher was looking for money with which to support an ongoing monarch program. She said, *"The Legion Club in our town does pull tabs, and they have, every year, about $100,000 to give back to the community from these pull tabs. But that's what we're looking at right now, is going to some of service-oriented groups like the Knights of Columbus and the Lions' Club, at least getting some matching funds."*

One teacher was working on plans to take a group of students to Texas in October during their intersession (kids are out of school). He said, *"We are going to be doing our own monarch research projects, since there's no more grant. I am raising money to do the research projects here. I'm expanding it to 30 children, rather than just two. We're working on the money to take the kids to Texas to follow the monitoring survey down to Texas, and we're looking at the possibility of two weeks rather than one week."* He would be using basically the same curriculum as the Institutes.

One teacher won a grant from a local electric company to buy a cage so that she would have a place to put them once they emerged, until they get ready to release them. *"So I've got my cage!"*

Personal lives
Several teachers told how this project affected their lives outside school:

> *"I have become almost TOO ABSORBED into the world of monarchs. I now travel to central Texas to help tag them in the fall since we don't get as many here in East Texas. I have already paid to go on a tour of the overwintering grounds this spring break. I read everything I can get my hands on about butterflies in general and have planted a butterfly garden at home and school to attract them."*
>
> *"My participation in this project has impacted me on a personal level, as well as professionally. I have learned to identify most of the local butterflies. It has developed an expensive photography hobby which helps to bring information into the classroom. I have converted most of my backyard landscaping into a butterfly garden. When I need critters for the classroom all I have to do is go into my yard and collect them. I have been able to share my knowledge with neighbors and teachers, raise more interest in environmental issues, and develop more people's interest in using organic techniques."*
>
> *"I am involving my children, my Mom, and even my Grandmother, who has added tropical milkweed to her garden in the hill country."*
>
> *"It has certainly made me more aware of my role in ecosystems." "I'd like to be an advocate for Oyamel Forest preservation in Mexico." "I want to get gardeners to plant milkweed in [my town]." "I plan to educate others and promote butterfly gardens in the community. I am interested even more in prairie restoration." "I'm a 'diehard butterfly fan' now."*

X. Benefits to the Scientists

Benefits to Scientists

Karen Oberhauser wrote,

> *"The teachers and students made important and real contributions to our understanding of monarch biology. This is especially true for those that have continued the monitoring year after year, but all the data are interesting and relevant. In addition, many of their group projects led to additional work by them and us, and have also made important contributions to our understanding. You should have seem the scientists gathered around the students discussing their work at the Monarch Population Dynamics meeting in May! It was incredible."*

Scientists and concerned citizens from Canada, Mexico, Australia, and the US met to discuss the current status of our knowledge abut monarch population dynamics. A major highlight of the meeting was the poster session, in which students and teachers who have conducted independent research on monarch biology presented their results. Much of the research presented at the meeting will be available in a book to be published next year. (Monarch Larval Monitoring Project newsletter, Volume 3, Issue 1, p. 2)

Benefits to Grad Students

In an interview, one of the grad students involved with the project all the way through said that she learned more about being a scientist because of this project than she might otherwise have.

> *"I'm a much better scientist from doing this project. In fact, I learned a lot more about science from this project than any other part of my graduate education, so I don't know what I would have gotten out of graduate school if I hadn't done this."*

> *"As a graduate student you only get your project to learn how to do research, unless you do other collaborations. I've done other collaborations with Karen and Michelle and that's been good, but a lot of people don't. I had to work with all these different teams to help them come up with their end research project. So I got to experience coming up with the questions, designing methods over and over again. So I've got that down. So I'm much, much better than I ever would have been."*

--excerpt from Chapter One--Citizen Science: A Tool for Ecological Research. Prysby, M. D. 2001. Temporal and geographical Variation in monarch egg and larval densities (Danaus plexippus): An ecological application of citizen science. Master's Thesis. University of Minnesota.

> *"Although we did not initially anticipate using the results of these projects in our own scientific research, almost all of the independent projects involved novel questions with previously unknown answers. We have published all of the projects on the Web, and have used their results for several purposes. First, the projects have identified interesting patterns in monarch*

ecology and behavior that have sparked new questions. For example, a project measuring reproductive diapause in natural populations of monarchs migrating through Texas led one of the scientist mentors to conduct additional experiments on the effects of the Texas environment on reproductive status in monarchs (B. Calvert, pers. comm.). In this way, the projects are like doing pilot studies on widely varying topics, allowing researchers to identify topics that might be worth further pursuit.

"Secondly, we have used results of the projects as additional pieces of information when conducting research on related topics. For example, one teacher-student team made detailed observations on monarch growth and development as part of a study examining the effects of larval consumption of their chorion (eggshell). These observations proved useful in a separate study when we needed estimates of the relative development times of the larval instars. We did not originally anticipate using the data in this way, but the data were perfect for providing the background information necessary for our model. Overall, our collaborations with students and teachers led to an expansion of the scientist mentors' research interests and an injection of fresh ideas."

--excerpt from Prysby, M. D. 2001. A Meeting of Monarchs and Citizens: Volunteers Discover Butterfly Biology. Wild Earth. (in press).

"These programs are typical citizen science projects, in which volunteers participate mainly in the data collection step of the research process, following a set protocol. But some monarch citizen scientists are doing independent research, and their findings also have been important. The Monarchs in the Classroom program, directed by Dr. Karen Oberhauser at the University of Minnesota, teaches students and teachers to ask their own research questions about monarchs and to design and carry out studies to answer them. While some of these studies are not important for conservation efforts (e.g., How does rock music affect monarch metamorphosis?), many are of keen interest to monarch scientists and conservationists. For example, students and teachers in Texas have carried out a multi-year study of the reproductive status of monarchs migrating through Texas in the fall. They have found that many of these butterflies are reproductively active. This finding challenges the idea that migrating monarchs are not mating or laying eggs, and it is causing scientists to re-think the theory that migration and reproductive diapause (a state of arrested development) are coupled in the species."

Benefits to Science from Teachers' Points of View

There were two specific examples of teacher/student teams whose team research projects had findings that were of great interest to scientists.

First example:

"One of the most interesting things that my students discovered this year deals with the presence of monarch eggs and caterpillars here in the fall. Our monitoring site for Michelle is across the street, about 100 yards from our butterfly garden on campus. The species of

milkweed in the field is A. virdis, the common milkweed for this area of Texas. On the other hand, we have tropical milkweed, A. currisavica planted in the garden. We had eggs and caterpillars in both places, but for several weeks, we had 100+ eggs/caterpillars in the garden whereas there might be 10 or so eggs in the field. The tropical variety is much taller and received regular water whereas the common field milkweed experienced quite a drought this summer, though it was amazing how well adapted it was to drought. The plants were still in pretty darn good shape after 92 days of no rain. In addition, there were numerous nectaring flowers in the garden as opposed to few in the field. Karen thinks we need to do a formal study on the effects of tropical milkweed species on monarch populations in Texas. Additional interesting information came from our migration study. We tagged more than 200 monarchs in the garden this fall. On numerous occasions, we recaptured the same tagged monarchs for one to two weeks. That tells us that they were in no hurry to migrate, even late in October. Many of the females also had spermatophores, which is not surprising based on the number of eggs we had in the garden."

Second example:

A second teacher and her student researchers, as well as project leaders, Karen Oberhauser and Bill Calvert were very excited about their team research project. They are actually going to replicate their experiment in fall 2001. They worked with a scientist from the university in their town. The teacher described their project, *"We simulated acid rain and we took a diluted sulphuric acid rain recipe. Basically, we replicated acid rain and we used spray bottles or those atomizers and then we sprayed them on the caterpillars and the leaves and whatever. The scientist that was working with us at the university says, "Denise, I don't want to say anything to your students, but 3.5 is actually pretty strong, pretty acidic. You're just going to kill those caterpillars.' And what we found out was, the caterpillars that had the strongest acid rain came out the largest. My daughter happened to be a part of the science group, and I asked 'why do you think that acid rain didn't kill those caterpillars?' In two seconds, my daughter says, 'Mom, that's easy. Those caterpillars get rid of their skins every other day when they molt. The acid probably didn't even have time to hurt them.' Maybe, if anything, it built up their immune system so they ate more and they were hungrier. As an adult, I would never have dreamed of that. And here, my 6th grade daughter – Miss Ph.D. in acid rain."*

They have been asked to replicate the study because they did not monitor the monarchs once they emerged as butterflies. *"We probably should have kept some to see if they had a shorter lifespan or whatever, and we didn't. Because even if they're big, what if they die after a week because – who knows?"*

XI. The Future

Continuing the work

Texas and Minnesota teachers and scientists are making plans for continuing the work of this project. Because of the expense of transporting teachers and students to and from Texas, the two states are planning separate projects for the future.

Karen Oberhauser, Michelle Solensky, and Beth Lavoye, University of Minnesota project staff, and Lee Schmidt and Dawn Cameron, Science Museum of Minnesota project staff, spent three days at a planning meeting at Selah in Texas. Four Texas teachers from the project, along with Bill Calvert, scientist from Monarch Watch of Texas, and David and Margaret Bamberger, owners of Selah Ranch, Johnson City, Texas, are planning to replicate much of this project in the coming spring, summer, and fall 2002 and beyond. They will seek Eisenhower and other grants.

Planning for continuing this work in Minnesota is also in progress. Eisenhower funds will be sought in order to offer a hybrid of the Monarchs in the Classroom and this Monarch Monitoring Project to Minnesota teachers.

Issues considered in planning

Many of the factors considered by the planning groups for continuing the work of this project are scattered throughout this report. A few issues not covered in other parts of the report are included here.

Mixing middle and high school teachers and students
If the project staff could have all the teachers they wanted, they might separate the grade levels – have a middle school approach and high school approach. But they did not have that luxury with this project. One possibility might be to split into two groups for some parts of the institutes.

When high school and middle school students are in the same group, there is a disparity in background knowledge and background experience. Middle school teachers might conclude that it was for high school. If there were only middle school students, they might have been able to see how to gear it towards middle school level students.

On the other hand, it was valuable that middle school and high school teachers were in one place where they could actually talk to each other about what happened at the other level. A lot of them didn't know. Also, some of the teachers taught both anyway – both middle school and high school.

The monitoring part of the project was easiest for the middle school teachers because the students weren't as busy in the summer. Middle school teachers were also more able to bring all the stuff back into their classroom because they had more freedom to teach what they wanted instead of having to stick to a set curriculum.

Scheduling an institute during the school year
Being gone during the school was a significant problem for teachers and students. In the future, project staff would recommend having both weeks during the summer. A Science Museum staff member said they get many more applicants for their other summer courses when it doesn't involve getting off of school.

Having two separated weeks
Project staff thought two weeks were needed in order to do everything they needed to do. They wanted the two weeks to be separated so that participants could do a research project in the interim. It was time for teachers to try out the activities and then come back and talk about what they did and what problems they ran into.

Teachers as mentors
Project staff talked about ways to get teachers who completed the programs to be mentors for the teachers who were trying to implement research techniques from the program. They felt the teachers were more equipped to know how to implement some of these things in the classrooms than the scientists were.

That would be an advantage for the Minnesota program. There is a network of teachers with the Monarchs in the Classroom program. They have the annual Monarchs Fair, and they have a yearly reunion, and, Karen Oberhauser said, "50% of them just kind of get with the program and stay with it and just maintain contact with us."

Appendix A1

District Expenditures for Teacher Travel and Lodging
Final Report

Report from Lee Schmitt
Science Museum of Minnesota

Group 1

St. Peter (2 teachers)	1019.22
	509.61
Wayzata HS	509.61
Willow Creek MS	509.61
Century HS	446.09
Cloquet MS	446.09
Cloquet HS	436.09
Lamar HS	525.09
John Jay HS	

Group 2

Heart of the Earth	536.83
Woodbury JH	536.83
Northview JH (2)	1073.66
Lakewood	536.83
Humboldt JH (2)	1073.66
TMI (2)	1032.80

Group 3

First Colony MS	439.39
Pleasanton HS	533.44
Mance Park MS	533.44
Sparta HS	526.90
Amery MS	526.90
St. Hubert	526.90
St. Croix Falls MS	526.90
Hamilton JF	533.44
Wylie HS	433.44
Minnetonka MS	526.90

Group 4

TMI (2)	1033.38
Westview MS (2)	1180.38
Science Academy	669.19
Decatur HS	417.69
Pacelli HS	553.69
Miss. Heights MS (2)	1047.38
Ordean MS	591.69

Group 5

New Country	535.19
School	580.94
Bemidji MS	503.09
Scottsburg HS	429.19
Blue Ridge HS	535.19
Jordan Park	535.19
School	535.19
Monticello MS	
St. Mark's	
School	

Total (all groups) $23,447.05

Appendix A2

School In-kind Support Form

Monarch Monitoring Project

A Teacher/Student/Scientist Research Project
funded by the National Science Foundation

Please complete the following form indicating the in-kind costs your school or district has contributed to support research-based learning as a result of the involvement of your teacher and students in the Monarch Monitoring Project. This is to show that your school is providing continued support for your teacher's efforts to involve students and other teachers in active research-based learning in your school. Thank you for your time and effort.

School: _____

School Address: _____

Teacher Participant: _____

Field Research and Student Project Support

Supplies	_____	Equipment	_____
Transportation	_____	Field Trip expenses	_____
Planning time	_____	Substitute costs	_____
Other	_____	Other	_____

Total _____

Technology and Dissemination Support

Computer	_____	Software	_____
Internet access	_____	E-mail services	_____
Phone	_____	Copies	_____
Travel	_____	Release time	_____
Other	_____	Other	_____

Total _____

I attest that the amounts on this form are not from federal funds and represent the in-kind costs this school has incurred in order to support our teacher's effort to implement research-based learning in the classroom and to disseminate information to teachers, students, and Monarch Project personnel.

Principal's Signature: _____ Date: _____

Appendix A3

Monarch Monitoring Project

Final Report - School In-kind, Non-federal, Project Support for Teacher Participants

from Lee Schmitt - Science Museum of Minnesota

School District	Field Research and Student Project Support	Technology and Dissemination Support	Total In-kind
Group 1 (8 of 8 schools)			
Lamar High School	10321	2750	13071
John Jay High School	3949	3020	6969
St. Peter High School	500		500
Century High School	965	445	1410
Willow Creek Middle School	2100	10076	12176
Cloquet High School	960		960
Cloquet Middle School	465		465
Wayzata High School	2435	583	3018
Group 2 (5 of 6 schools)			
Woodbury Junior High	1150	1035	2185
Northview Junior High	1200	1610	2810
Lakewood Academy	285	194	479
Humboldt Junior High	3800	375	4175
Texas Military Institute	3215	8850	12065
Group 3 (7 of 10 schools)			
St. Croix Falls Middle School	660	9	669
Sparta High School	1025	644	1669
Minnetonka Middle School	225		225
Mance Park Middle School	620	150	770
Hamilton Junior High	3800		3800
First Colony Middle School	1600	2285	3885
Pleasanton High School	175		175
Group 4 (7 of 7 schools)			
Texas Military Institute	3215	8850	12065
Westview Middle School	554	125	
Science Academy of South TX	303	3340	3643
Decatur High School	1375	610	1985
Pacelli High School	973	134	1107
Mississippi Heights Middle	1720	910	2630
Ordean Middle School	640	2025	2665
Group 5 (4 of 7 schools)			
Bemidji Middle School	293	1627	1920
Jordan Park School	2155		2155
Monticello Middle School	2000	600	2600
St. Marks School	242	90	332
Totals	52920	50337	102578

Appendix B

Table B1. Teacher Evaluation Survey of Institute I

		How activity taught you		How activity will affect your teaching	
Learning Experience	**Group**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Teacher/staff meetings	1	NA	NA	NA	NA
	2	3.55	1.13	2.75	1.83
	3	4.20	.79	4.30	.82
	4	4.56	.73	4.44	.88
	5	3.43	1.27	3.29	1.25
Working in teams to design research projects	1	5.00	0	5.00	0
	2	4.11	.78	4.33	.71
	3	4.70	.67	4.70	.67
	4	4.78	.44	4.67	.71
	5	4.28	.38	4.85	.38
Learning about monitoring and censusing	1	4.88	.35	4.67	.50
	2	4.67	.50	4.11	1.26
	3	4.80	.42	4.78	.44
	4	4.67	.71	4.56	.73
	5	4.43	.79	4.43	.89
Observing monarchs in "life cycle stations"	1	4.75	.46	4.33	1.32
	2	4.33	.71	4.00	.87
	3	4.88	.35	5.00	0
	4	4.56	.73	4.89	.33
	5	4.86	.38	5.00	0
Research presentations by scientists	1	4.75	.46	4.22	1.09
	2	4.33	.71	3.22	1.20
	3	4.80	.42	4.70	.48
	4	5.00	0	4.22	.83
	5	3.43	1.27	3.14	1.23
Learning about the study of animal behavior	1	4.57	.53	4.50	.75
	2	4.78	.44	4.33	1.11
	3	4.90	.32	4.80	.42
	4	4.75	.46	4.50	.93
	5	4.00	1.00	4.00	1.00
Learning about the study of interspecific interactions	1	NA	NA	NA	NA
	2	3.88	.93	4.22	1.09
	3	4.60	.52	4.50	.72
	4	4.67	.50	4.44	.73
	5	4.29	.49	4.29	.49

Note: The first institutes for Groups 1, 3, 4, and 5 were in Minnesota; Group 2 was in Texas. Teacher numbers: Group 1 = 9; Group 2 = 9; and Group 3 = 10, Group 4 = 10, and Group 5 = 7

Appendix C1

Pretest and posttest results on science knowledge
Monarch Monitoring

For Groups 3, 4, and 5, pretests and posttests were administered to measure the science knowledge participants were expected to know at the end of the two weeks of institutes. The pretest was completed during the first session of the first week before any science content was introduced. The posttest was completed at the end of the second week after all science content had been introduced.

See below the test questions, expected answers, and the scoring rubric for rating the responses. The possible score could be 14 or above depending on how much detail participants included.

Table C1

Scores	Pretest # teachers	Posttest # teachers
5	3	
6	4	
7	4	1
8	2	1
9		
10	3	1
11	1	2
12	2	2
13	1	8
14	1	2
15	1	5
16		
17	1	1

Mean of the pretest = 9, Standard deviation = 3.49
Mean of the posttest = 12.83, Standard deviation = 2.31
$P < .001$

Appendix C2

Monarch Monitoring Project: Post-Assessment With Expected Answers

This may look familiar, since many of you answered similar questions before you started learning about monarchs last summer. We're interested in how you answer them after you've participated in this program. You'll need to fill in your names for evaluation purposes, but program staff will not see your answers nor will this be used in determining your grade or payment for the course.

Please answer the questions on both sides of this page. Do not use resources other that what is in your brain!

1. About how many eggs does an average female monarch produce during her lifetime (assuming she lives a normal lifespan)? Circle the closest number: 10 100 700 2000

The best answer is 700

2. **Describe the life of**

- **A monarch that begins life as an egg in MN in early August**
- **A monarch that begins life as an egg in MN in early July**

For each, tell us approximately how long it will live, and what it will do when it is an adult.

The main point here is that the August egg will turn into a migratory adult. It will become an adult in early September, migrate to Mexico, live there all winter, and then return north in the spring to reproduce. It will live about 8-9 months as an adult.

The July egg will not migrate. It will emerge as an adult in early August, begin reproducing when it's about 4-5 days old, and then die after about 4 weeks.

3. **Define the word instar.**

One of the stages between molts of a larva. (They might say that monarch larvae go through 5 instars.)

4. **You have been asked to estimate the number of monarch larvae in a nature reserve near your home. This reserve contains one large field with lots of milkweed plants in it. There are too many milkweed plants to check all of them; in fact you don't even have time to count all of the milkweed plants. What could you do?**

Hopefully, they'll say here that they should sample the milkweed using some kind of random sampling process. They practice several sampling methods in the class – walking a transect and counting the number of plants in randomly chosen meter square areas, then using the average number of plants/meter to estimate overall density. They also learn a process called point quadrant method, but that was pretty complicated.

Once they know the number of plants in the field, they can estimate the number of larvae by randomly sampling plants and seeing if they have larvae on them. If they find that a certain percentage of the plants they sample are occupied by larvae, they can multiply this percent by the total number of plnats in the field.

This is a complicated question (on purpose). It really requires two steps – estimating the number of plants and then the percent of plants occupied. If they get they idea of random sampling, we've made a big step!

5. **You observe ants, aphids, and a monarch caterpillar on a milkweed plant.**
- **List two ways that these insects might be interacting with each other and with the plant.**
- **List a question that you could ask about the interactions between any of these organisms.**
- **How could you answer this question? (Don't worry about details, just summarize the process.)**

Many possibilities! We want them to have ideas about how these species might be affecting each other and the plant, and then think of questions and ways to answer their question.

6. **You wonder if female or male monarchs are larger. You measure the wings of 5 males and 5 females. The male wings are 0.54, 0.49, 0.47, 0.53 and 0.54 mm long. The female wings are 0.53, 0.50 0.44, 0.51 and 0.56 mm long. What can you conclude (without using a calculator)? What else could you do to answer this question?**

What we'd really like here is to have them say that even though the male wings are longer on average, there is a lot of overlap, and this is a small sample size that wouldn't allow them to conclude that either sex is larger than the other. Hopefully, some of them will say that they could do a t-test to see if the different is statistically significant. They might also say that you could measure both wings, or weigh them to look at other indicators of size.

Appendix C3

Monarch Monitoring Project
Scoring Rubric
Test of Teacher Knowledge of Science Concepts

Question One:
1 point

Question Two:
1 point for knowing that the August egg will turn into a migratory adult
1 point for each piece of additional information (becoming adult in early September, migrating to Mexico for winter and returning North in the spring, living 8-9 months as an adult)
1 point for knowing July eggs don't migrate
1 point for each piece of additional information (emerging as an adult in early august, reproducing when it is four or five days old, dying after about 4 weeks)

Question Three:
1 point for "one of the stages between molts of larvae" or saying that larvae go through five stages

Question Four:
2 points total – 1 point for mentioning random sampling of milkweed plants and 1 point for mentioning the need to sample for the number of larvae on plants

Question Five:
1 point for each way listed that insects interact with each other and the plant
1 point for a listed question
1 point for answering the question

Question Six:
1 point for being aware of small sample size and overlap even though males are larger
1 point for mentioning doing a t-test
1 point for mentioning the possibility of measuring both wings or weighting them to look at other indicators of size

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